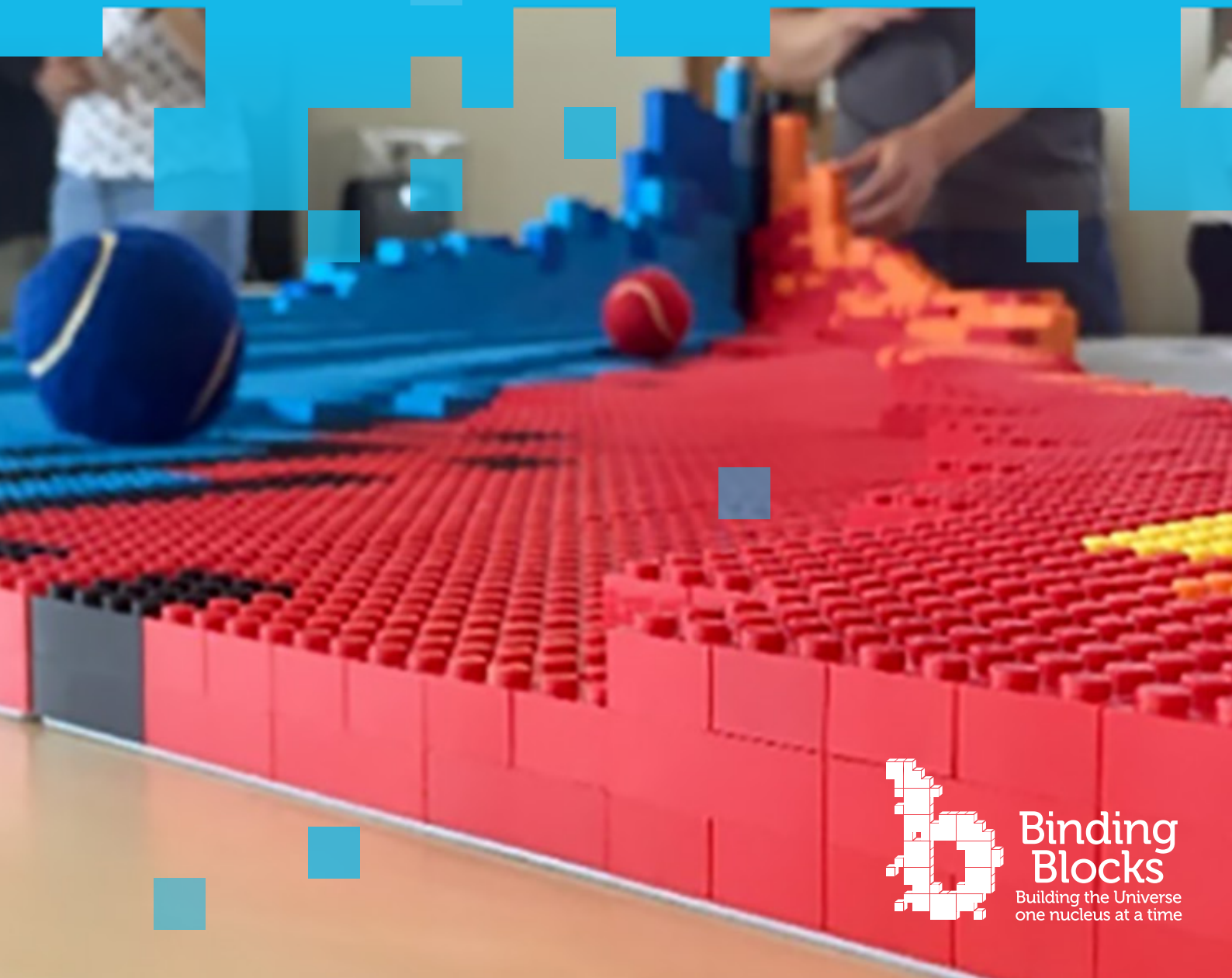
UNIVERSITY of York

Inspiring the Next Generation about Nuclear Physics

Using The Binding Blocks Programme

An Independent Evaluation by Paul Rhodes Consulting



Binding Blocks
Building the Universe one nucleus at a time

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Inspiring the Next Generation about Nuclear Physics Using The Binding Blocks Programme

An Independent Evaluation by Paul Rhodes Consulting.

December 2020[1]

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Executive Summary

Introduction

The Binding Blocks project engages the public and young people with nuclear physics research. Activities centre on an 8m-long representation of the Nuclide Chart,[2] built using over 25,000 LEGO® bricks.

Since 2015, just under 30,000 young people and members of the public have taken part in Binding Blocks events and more than 10,000 have watched educational promotional videos online.[3]

Furthermore, 375 undergraduates, postgraduates and researchers have taken part in Binding Blocks training.

The project engages target audiences through a range of programmes:

1. Nuclear Masterclasses for A-level (or equivalent) students. Offered both in-person and online, these introduce the key concepts of nuclear physics before focussing on applications including nuclear astrophysics, fusion, and medical physics.
2. A school loans scheme comprised of a curriculum-linked LEGO® workshop for A-level (or equivalent) students.
3. Teacher CPD programmes (run in conjunction with the National STEM Learning Centre)
4. Exhibitions targeted at family audiences centred around the building of the LEGO® chart.

The project has been supported by the Science and Technology Facilities Council (STFC) and the University of York. To date, the Binding Blocks team have developed 23 partnerships with other universities and institutions in the UK and overseas.

The evaluation findings presented in this report are drawn from feedback provided by a sample 209 students attending face to face Nuclear Physics Masterclasses (2016-2019) and 388 young people taking part in an online Nuclear Physics Masterclass during June and July 2020.[4]

Summary Findings

Three 'Key evaluation questions' have been developed to frame the findings and subsequent evidence gathering.

1. Does the Binding Blocks programme inspire, and contribute to students wanting to study physics in the future?
2. Does the Binding Blocks programme play an effective part in teaching the concepts of nuclear physics and developing confidence to talk about the subject with non-specialists?
3. Does the Binding Blocks programme help to change people's views on nuclear physics?

[2] https://www.york.ac.uk/physics/public-and-schools/secondary/binding-blocks/

[4] Due to inconsistencies in the questions used two masterclasses were not included in the overall analysis (Daresbury and York 2018), but their feedback is consistent with the overall sample. Base sizes for responses vary.

Does the Binding Blocks programme inspire, and contribute to students wanting to study physics in the future?

This positive encounter with physics, centred around the creation of an 8m-long representation of the Nuclide Chart,[5] built using over 25,000 LEGO® bricks, can be seen to influence young people's subject choices in higher education. As masterclass students are studying A level physics and, based on this sampled evidence, are already intending for the most part to go to university, the extent of the contribution from any one programme is likely to be small.

- Nevertheless, almost three in ten students said they were more likely to go to university as a result of attending a face-to-face Binding Blocks Nuclear Physics Masterclass[6]
- 35% said that they were now more likely to study physics in the future, while 57% said there was 'no change'. 8% of participants were less likely to study physics
- By comparison. over two-thirds of all students (68%) taking part in the online Nuclear Physics Masterclass said they were more likely to study physics in the future
- Further analysis by gender shows females were more likely to strongly agree that they were inspired by the online Nuclear Physics Masterclass (63%) compared to their male peers (45%)

The online Masterclass participants consistently reported how the content enabled them to realise the exciting breadth and potential of physics, which felt different to the curriculum studied at A level.

> **"The medical physics was the area that felt the most interactive. It was very interesting as I did not know in a great detail how physics is used in medicine!"** (Online participant)
>
> **"The inspiring course offering really made me re-evaluate my options to consider studying physics".** (Online participant)

The suite of workshops is adaptable, and enhanced by the facilitation skills of the Binding Blocks programme team and volunteers. The volunteers are gaining subject knowledge, confidence, pedagogical skills and approaches and the desire to continue talking and sharing their interest in nuclear physics with others. The reputations of partner universities are increased by the collaboration and, through trained and paid KICK-START internships for PhD students, there is an increasing cohort of people able to support and lead sessions. York alumni and former interns work across the globe.

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[5] https://www.york.ac.uk/physics/public-and-schools/secondary/binding-blocks/
[6] 28% of 133 valid responses

The timing of interventions can sometimes be more significant than the scale of the programme and it will be interesting to follow up with online Nuclear Masterclass participants; inspired during a national lockdown, to assess how formative that experience turns out to be in their post 18 choices. One parent fed back to the Binding Blocks team:

> **"At a time when so much of his learning was disrupted, it was especially valuable to structure his time, to learn and to feel that sense of achieving something."**

Does the Binding Blocks programme play an effective part in teaching the concepts of nuclear physics and developing confidence to talk about the subject with non-specialists?

Student volunteers affirmed the importance of being able to talk about nuclear physics with non-specialists, be it funders, members of the public or others in the academic and research spheres. The Binding Blocks programme provides stimulus in abundance to create interest and discussion, and the team have learned how to adapt the content to the age of their audience. The programme differs from other outreach approaches which typically use a combination of experiments and stage craft to create an audience reaction. The Binding Blocks programme is at once familiar, since it is made of LEGO®, but also novel. Building the kit takes time and perseverance.

Teachers agreed that the programme was aligned to the curriculum, and could envisage, to varying degrees, using the concepts from the workshops and the approach as part of their pedagogy.

Student volunteers, benefitting from the training which offers a 'dry run' with the kit, talked of increased confidence and the knowledge to deliver the programme to diverse audiences.

> **"I love it when you get that 'wide-eyed response' and the realisation that a light bulb has gone on, and the connection has been made."**

The Binding Blocks programme team, and a growing network of university partners in the UK and overseas, have tested and developed their capabilities over nearly 80 events. As a programme it is arguably well positioned as the knowledge leader for the sector on nuclear physics outreach. The programme is also a known and versatile 'umbrella brand' for engagement work around nuclear physics.

> **"Binding Blocks is unique... All the presenters and workshops bring something unique. Each appeal to a different learning style to inspire the next generation."** (Online participant)

The next chapter in the Binding Blocks programme evolution will require new approaches, and efficacy in working through teachers to use the kits or virtual equivalents, and delivering to younger students. The active engagement and support from 'early adopter'[7] teachers will be critical in adapting and refining this more indirect approach to engagement.

> **"I always like being able to share. It's a fundamental part of your role. A researcher needs to be able to explain, it's morally important. My time with Binding Blocks tied it all together. As I was getting excited learning about research, I was able to share that excitement with others."** (KICK-START PhD student)

Does the Binding Blocks programme help to change people's views on nuclear physics?

This independent evaluation concludes that, based on the feedback from school students, volunteers, teachers, members of the public attending exhibitions, and partner organisations, the Binding Blocks programme is making a positive, practical contribution to changing views about nuclear physics.

> **"While I already loved physics, the course deepened my understanding of the field, giving me some of the tools needed to work with the kind of figures used. It was as though I had a 2D picture of nuclear physics, and the Nuclear Masterclass made it 3D."** (Online participant)

Given the gender imbalance in physics[8], it is noteworthy that females were less likely to be already planning to study physics, they did respond more positively than males to both the face to face (where they were in the minority) and online masterclasses (where the gender balance was more even).

Females were also more likely to strongly agree they were inspired to learn more about nuclear physics (65% compared to 50%). Women were more than twice as likely to give a 10 / 10 response to the question 'would you recommend the masterclass to your peers' (39% compared to 17%).

Females from a BAME background[9] were more likely than other females and the overall sample to say they were inspired by the masterclass. Albeit based on a small sample, it may merit further investigation to explore the finding that as a result of the Online Nuclear masterclass, BAME females were more likely to want to study physics in the future (81% compared to 67% for non BAME females and 68% for the sample as a whole.)

[7] Typically, 12-14% of the total market, in this case, of secondary school physics teachers – totalling 6,642 in 2018-2019 according to DfE statistics. This would provide a target of 900 teachers for Binding Blocks to engage. Sources: https://ondigitalmarketing.com/learn/odm/foundations/5-customer-segments-technology-adoption/ and https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england

[8] While more females are now taking STEM subjects than males. 2019 figures showed that females accounted for 23% of exam entries in Physics. https://www.stemwomen.co.uk/blog/2019/08/why-are-female-students-now-outnumbering-males-in-a-level-science

[9] N=48. This group were less likely to say that without the masterclass, they would have done something comparable.

For a minority, the experience confirmed their view that the subject is difficult, but for the majority, the level of challenge was judged to be 'about right'.[10]

> **"I didn't find anything 'too difficult' just the 'right amount of challenging'."** (Online participant)

Binding Blocks illuminates the potential of the subject both for future research and how different disciplines within the subject collaborate with one another. This is perhaps even more apparent online where it is possible to feature speakers from across the world, from a range of ethnic backgrounds and genders.

It is not only young minds that are being influenced, but teachers accompanying young people or being trained directly are feeding back positively. The Binding Blocks project engages the public and young people with nuclear physics research, with the modular approach enabling the programme to remain contemporary and to reflect the specialties of the host organisation.[11]

Supporting exhibitions chart the course of the subject and its applications, and are greatly enhanced by the student volunteers who can pose and respond to questions, as well as engaging people with the skilful use of 'artefacts'.

Success factors

Evaluation evidence and feedback has highlighted the following as key 'ingredients' in the effective delivery of the Binding Blocks programme, aspects that were seen to be working well. There is scope to consider the potential for the Binding Blocks to take a more formalised leadership role for public engagement for nuclear physics.

[10] Looking at feedback from 7 different workshops, on average 53% of participants rated the level of difficulty to be 'just right' (25% 'somewhat hard and 16% 'somewhat easy'.). Further analysis revealed that the level of difficulty was a key factor in determining overall satisfaction with the event. Participants who found the difficulty to be 'just right', 'somewhat easy' or 'somewhat hard', were more likely to rate it with a 4 or 5 out of 5, and those who found it 'too easy or too hard' rated it 2 or 3. Females were consistently more likely than their male peers to say the level of difficulty was just right.

[11] For example, masterclasses at the University of Glasgow feature hadron physics, which is a speciality there.

Recommendations for further research and development

The independent evaluator would like to present the following five recommendations to further understand the outcomes Binding Blocks is contributing to.

1. Develop a learning community of practice for the Binding Blocks programme to share successes and learning, engage in evaluation, and pilot new approaches.
2. Commit to extending, in a proportionate manner, the evaluation framework for the Binding Blocks programme, in order to develop assessments of the extent and durability of the outcomes created at masterclasses and other events. Standardise the evaluation forms used, their ongoing completion and regular analysis and review.
    a. Based on evaluation feedback to the online masterclasses, commission qualitative research with females, both BAME and non-BAME, to test the hypothesis that the online format is a more equitable format.
3. Collaborate with the UK Physics community to refine and share the pilot online materials.
4. Assess the feasibility for the Binding Blocks programme to become a hub for people who want to talk about physics, and widening participation.
5. As part of the projected expansion into Key Stages 2 and 3, consider whether the Binding Blocks programme can be aligned to the Children's University Programme, which has been assessed as a 'promising project' by the Education Endowment Fund. [12]

[12] The approach uses after school clubs as a vehicle to boost academic attainment. https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/childrens-university/

1 Background

Nuclear Physics teaching and research underpins not only the nuclear sector, but also a host of wider scientific and social applications, perhaps most extensively in medicine.

> **"Techniques employing nuclear particles and radiation to understand, diagnose and cure diseases are increasingly important in healthcare. Much of the underpinning research and development is carried out in institutes devoted to nuclear physics studies. Indeed, nuclear physics has since the beginning been characterized by fast implementation of its discoveries to the benefit of society. Its medical applications constitute the fastest science transfer from basic research to social applications."[13]**

> **"The UK's supply of nuclear engineers is dependent on a healthy nuclear physics research community."[14]**

The scale of this skills shortage has been illustrated by the Social Market Foundation, which found that despite recent increases, there remains a shortfall of around 40,000 STEM (Science, Technology, Engineering and Maths) graduates in the UK each year.[15]

The root causes of labour market skills shortages can be traced back to young peoples' education. Lower than optimal take up of physics, from A level onwards, particularly by young women, presents a 'grand challenge' to make STEM careers appealing to greater numbers of young people.[16]

Research conducted by the Institute of Physics observed the power of outreach work, not just for the benefit of the nuclear physics community, but all STEM subjects.

> **"The wonder stimulated in young people by basic research in fundamental science inspires them to enter and progress in scientific education. Interest in nuclear physics, in common with the other STFC science programmes, is often quoted by young people as one of the key motivators to study science, even if they ultimately study another area such as life sciences, engineering or work in industry."[17]**

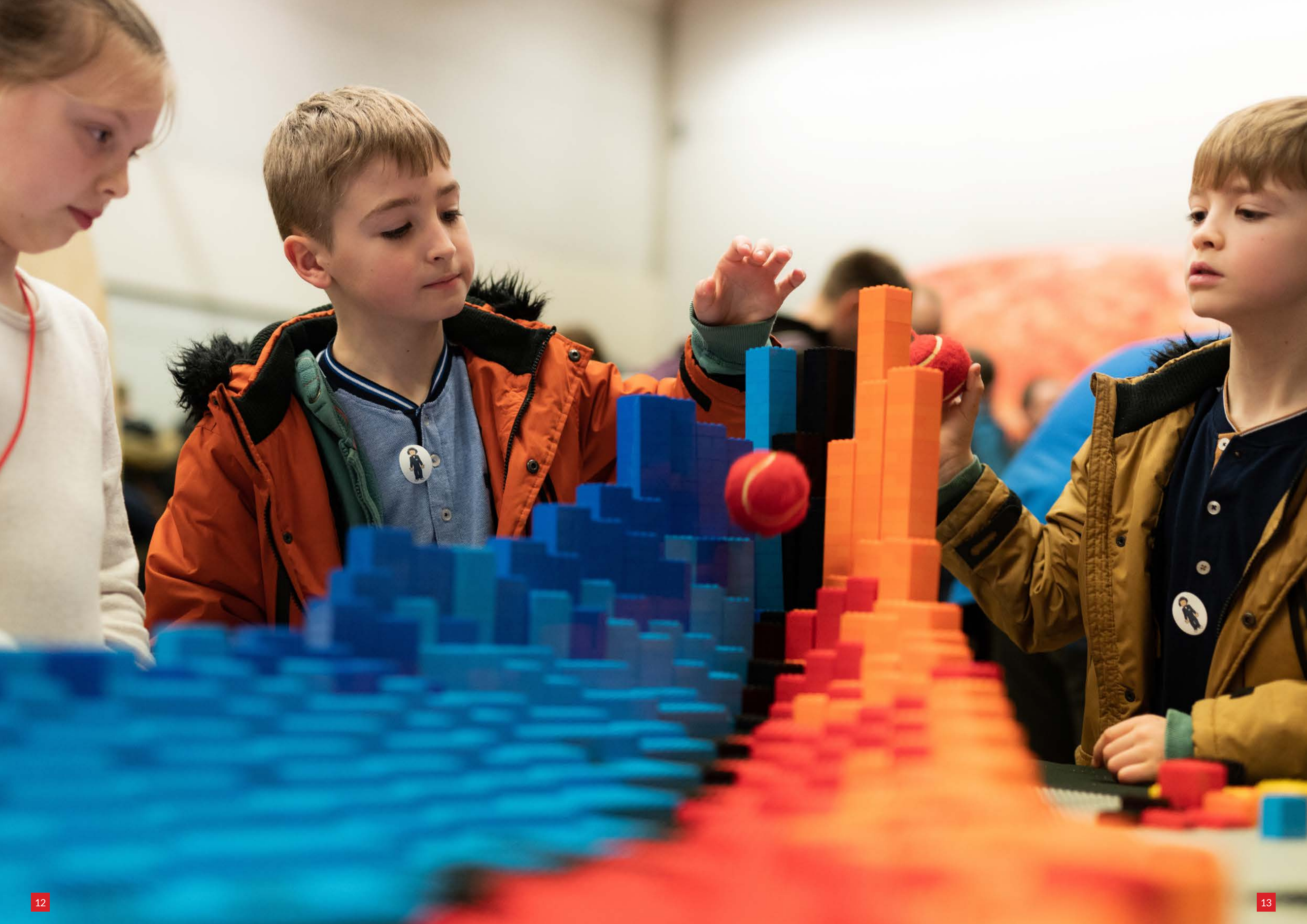
[13] Nuclear physics for medicine: how nuclear research is improving human health (Bracco, A, 2015). See also National Academies Press: Nuclear Physics: The Core of Matter, The Fuel of Stars (1999).

[14] Institute of Physics, Evidence submission to the Innovation, Universities Science and Skills Committee. Reproduced in Engineering: Turning Ideas into Reality, Fourth Report of Session 2008-09.

[15] An Institute of Physics Report (May 2018) 'Why not physics? A snapshot of girls' uptake at A-level' http://www.iop.org/publications/iop/2018/file_71495.pdf. This report quotes an Engineering UK estimate that a shortfall in the supply of engineering skills, which are underpinned by physics, is likely to cost the UK economy £27 billion a year from 2022.

[16] The Royal Academy for Engineering 2019 report 'Engineering skills for the future. Also, the 2013 Perkins Review revisited' stated that 'the uptake of physics at A level remains stubbornly low at around 35,000. Just 5% of the typical annual cohort. For girls just 7,000, which is 2 to 3% of the overall female cohort.' The situation improved in 2019, with a greater parity in the gender of STEM exam entrants. In Physics, females accounted for 33% of the total cohort. https://www.stemwomen.co.uk/blog/2019/08/why-are-female-students-now-outnumbering-males-in-a-level-science

[17] Institute of Physics, A Review of UK Nuclear Physics Research (2012).



The Binding Blocks Programme

The Binding Blocks project engages the public and young people with nuclear physics research. Activities centre on an 8m-long representation of the Nuclide Chart, built using over 25,000 LEGO® bricks.

The project engages target audiences through a range of programmes:

1. Nuclear Masterclasses for A-level (or equivalent) students. Offered both in-person and online, these introduce the key concepts of nuclear physics before focussing on applications including nuclear astrophysics, fusion, and medical physics.
2. A school loans scheme comprised of a curriculum-linked LEGO® workshop for A-level (or equivalent) students.
3. Teacher CPD programmes (run in conjunction with the National STEM Learning Centre)
4. Exhibitions targeted at family audiences centred around the building of the LEGO® chart.

The project is funded by the Science and Technology Facilities Council (STFC) and the University of York. To date, the Binding Blocks team have developed 26 partnerships with other universities and institutions in the UK and overseas.[18]

For in-person events, the full model is built during a half-day workshop with up to 100 teachers or 150 students or with larger numbers at public exhibitions. Scaled down versions of the equipment can be delivered in smaller spaces, shorter sessions[19] or as part of larger events.

Along the way, the builders are educated in:

1. Binding energy and decay modes
2. Nuclear fusion
3. Nuclear fission
4. Nuclear astrophysics
5. Nuclear physics in medicine
6. Exotic nuclei

A hands-on experience has been shown to develop 'situational interest', which can precede or augment the development of personal interest.[20] Binding Blocks gives participants just such a hands-on experience in actually building a nuclear chart.

> **"The Binding Blocks programme is a unique combination of a sensorial experience with a rational game in which participants (with some guidance depending on their age) discover concepts such nuclear mass, radioactive decay, binding energy, etc (all without a nuclear lab!!). It is difficult to think of another project that has the same active learning impact as the Binding Blocks programme."** (International University Partner)

[18] Source: https://www.york.ac.uk/physics/public-and-schools/secondary/binding-blocks/about/

[19] For example, at the Daresbury Laboratory, Binding Blocks is delivered as a two-hour session to half the participants, while the other group visit the radiation lab.

[20] Krapp et al., 1992, from: Virtual Avatar as an Emotional Scaffolding Strategy to Promote Interest in Online Learning Environment. Sanghoon Park, in 'Emotions, Technology, Design, and Learning', 2016. 'Situational interest is elicited by aspects of an object or a situation, such as novelty or intensity, or by the presence of interest-inducing factors contributing to the attractiveness of the situation.'(Krapp, 1999; Tobias, 1994).'

The Binding Blocks LEGO® activity is the centrepiece of a suite of nuclear physics workshops developed by the University of York and collaborating institutions (who jointly deliver events).

The Binding Blocks programme 'journey' began in 2015 with a successful public trial.[21] It was inspired by a nuclear chart seen by Dr Christian Diget in Japan, which was a static exhibit of a nuclear chart, one quarter of the scale of what became the Binding Blocks chart.

After the pilot, the development of the Binding Blocks programme has been implemented through a phased approach, supported by the Science and Technology Facilities Council, to purchase additional LEGO® resources and to develop and refine the expertise needed to deliver a range of themed workshops. York's team of academics and c.10 student volunteers (per event) can now run masterclasses for up to 150 students per event.

The target audience for the Binding Blocks programme masterclasses has been Key Stage 5 physics students and their teachers. Through teacher training and support, combined with upskilling research staff and students at other universities, the Binding Blocks programme is expanding their secondary-school reach across the UK nuclear physics community through additional Nuclear Masterclasses and Binding Blocks programme schools events delivered jointly with institutions across the UK.

With the Binding Blocks LEGO® workshop at the centre, host institutions can then customise their event by selecting 'satellite' workshops– for example on computational medical physics- to create a masterclass.

The Binding Blocks programme aims to support young people to become aware and interested in STEM subjects, and nuclear physics in particular.

> **"The LEGO® / Binding Block activity is engaging for people of all ages. As such, it has allowed me to explain nuclear physics concepts, to the youth and general public, which are usually covered at the physics undergraduate level. I believe that these activities are powerful in sparking interest on these subjects; th**rough them we are inspiring and motivating the next generation of scientists." (International University Partner)

Undergraduate and post-graduate training

The Binding Blocks programme team has achieved their aim to train 100 undergraduate and postgraduate student ambassadors across the UK through a hands-on training programme with clear progression routes into more specialist leadership roles. Student ambassadors are then invited to support the delivery of masterclasses, teacher training, and/or public engagement.

From 2018, 10 future leaders are being trained through a combination of three new 'KICK-START' awards (PhD-level internships), three graduate internships, and four undergraduate internships. The Fellowship project is focussed on 'integrating Binding Blocks programme within UK A-level (and equivalent) delivery of nuclear physics'.

[21] York Researchers' Night, LEGO Nuclear Chart, York September 2015, https://www.york.ac.uk/news-and-events/events/yornight/2015/activities/kings-manor/what-can-LEGO-tell-us-about-radioactivity/ *"At this event, we demonstrated that we can use the chart as a mechanism for researchers to talk with the public about their research by them highlighting on the chart which isotopes they study, as well as how and why they study them. This is what convinced us that the Binding Blocks programme should move ahead, and what gave us the foundation for the first two sets of funding (STFC and University)."* Dr Diget.

> **'Through these influencers, we will implement the Binding Blocks programme in schools using the nuclear chart to study cutting-edge research in nuclear science, linked with the secondary-school curriculum.'** STFC funding bid 'Leadership Fellowships in PE 2018'

This is facilitated through large (100+ participant) Nuclear Masterclasses, Teacher Training, and smaller scale in-school teaching by team members and teachers. Following the successful online pilot in June and July 2020, face-to-face engagement will be complemented by an online course which will be implemented both as a self-contained learning environment and integrated with the Nuclear Masterclass programme.

Partners

The Binding Blocks programme originated from the University of York has increased its reputation among university partners through Dr Christian Diget's public engagement fellowship and role within the UK nuclear physics community. The support of the STFC has been instrumental in enabling this to take place.

The approach and resources have been shared more widely across academic institutions from the UK Physics community to institutions overseas.

> **"Working with the University of York on the nuclear physics masterclasses (NPMC) allows our laboratory to maintain strong ties with the network of universities we are involved with. We are proud to work with these universities in order to provide students with a good understanding of the landscape of Nuclear Physics in the UK. We hope that the students who attend our NPMC will go on to value the work of STFC and the network of universities involved in the delivery of the project, and will be inspired to pursue a career in STEM."** (Daresbury Laboratory)

Engagement data

In-person masterclasses have been attended by 200-350 students per year, starting in March 2016, while 840 individuals took part in the first Binding Blocks Programme Online Masterclass in 2020.

From 2017-2022, it was envisioned that Binding Blocks programme would reach up to 10,000 students (directly and indirectly). Since 2017, at least. 3,935 young people have been engaged directly.[22]

In the same time period, separate events such as European Researchers Night, YorNight, the INPC (International Nuclear Physics Conference), the York Festival of Ideas, and exhibitions hosted by the Institute of Physics have reached over 15,000 members of the public (of all ages).

[22] This is the total attendance for 31 school events since 2017 (average attendance was 126 young people, with the modal figure 40). Young people will have also been present at events aimed at families and members of the public. In the same period, a total of 15,242 people attended 43 of these larger events (average attendance 760).

CPD workshops for teachers are on track to reach their target of c.500 science teachers from across the UK over a 5-year period, with an estimated 350 teachers reached by March 2020.[23] Complementing the research-related material provided through the participating research students, Binding Blocks workshop kits are made available for free to schools[24], and there is also an interactive Minecraft version of the chart available to download.[25]

In total, there has been £174,500 of funded support, with in-kind contributions of approximately £100k for staff and student support. Between 2015 and 2020, this direct funding, together with significant in-kind contributions, has enabled the planning and delivery of 78 events.

Online Nuclear Physics Masterclasses

The first online masterclass was delivered as a four-week programme (June and July 2020), aimed at students studying Physics in years 11, 12 and 13 (S5 and S6 in Scotland). As well as weekly webinars, there was a package of support including an online question forum.

In total, 1,155 participants signed up to take part, and 388 completed all of the required elements and were awarded certificates. This is a 34% completion rate.[26]

Monitoring data shows consistently high participation and completion rates, for the programme overall, and the modules within it. In total, there was 840 unique users over a four-week period. There were 549 unique users in week one, and 424 by week four. The evidence suggests users were logging in multiple times. There was a combined 'live audience' of 1,150.

The timing of this pilot, during the first national COVID-19 lockdown in 2020, gave participants a positive focus at a difficult time.

> **"As a parent of a child in year 11 /12 who just got their certificate, I wanted to thank you for this class. It was perfect for my son, really engaging and challenging enough that he is proud of his achievement.**
>
> **At a time when so much of his learning was disrupted, it was especially valuable to structure his time, to learn and to feel that sense of achieving something.**
>
> **I know how much effort goes into these packages so wanted you to know it was very much appreciated.** (Parent of child in Y11/12)[27]

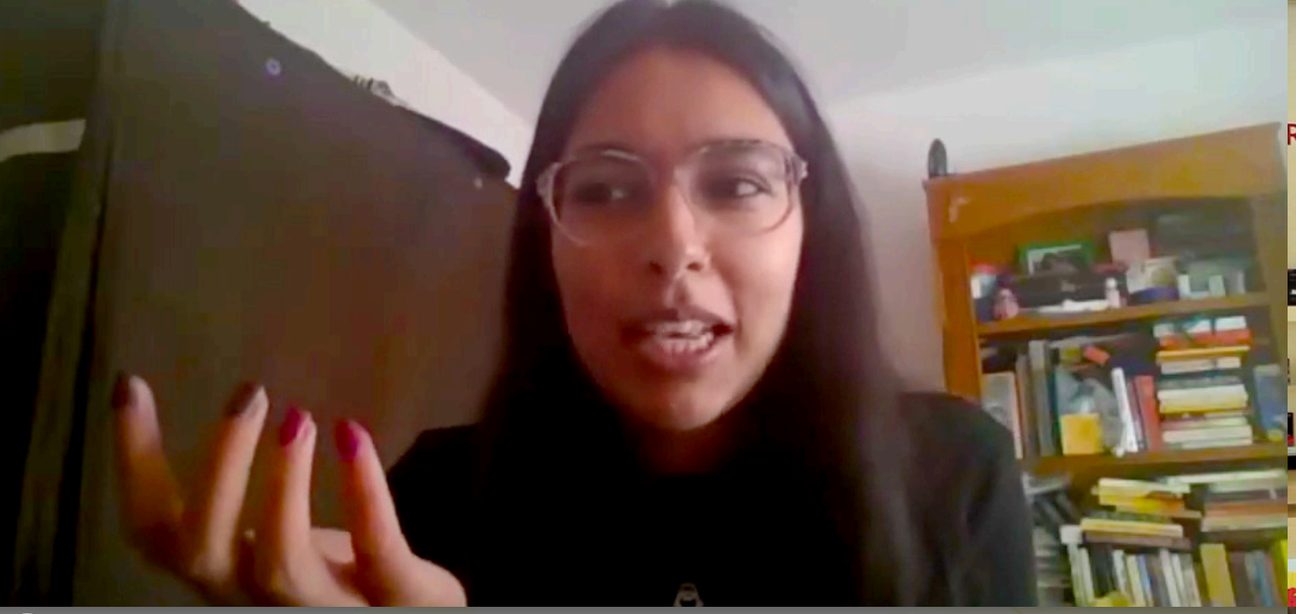
[23] A follow up evaluation survey is recommended, to explore how and to how many Binding Blocks has been used in classroom and extra-curricular settings. This cohort has been trained across c.10 sessions.

[24] This is a pilot programme, with 3 kits loaned to date. The cost to buy a full kit is in the region of £5,000 (April 2020 prices).

[25] ttps://www.york.ac.uk/physics/public-and-schools/secondary/binding-blocks/interactive/

[26] To put this in context, a meta review of completion rates for 221 massive open online courses (MOOCs) found a median completion rate of 12.5%. 'Completion rates (defined as the percentage of enrolled students who completed the course) vary from 0.7% to 52.1%, with a median value of 12.6%.' Jordan, Katy (2015). Massive open online course completion rates revisited: Assessment, length and attrition. International Review of Research in Open and Distributed Learning, 16(3) pp. 341–358. Completion rates were higher if the course was paid for, but the evidence also shows that learners have a different way of engaging with online learning, so may pick and choose content rather than working through the content in a traditional manner. Therefore, lower completion rates do not automatically equate to low value.

[27] Feedback volunteered to the Binding Blocks team following the Online Nuclear Physics Masterclass, Summer 2020

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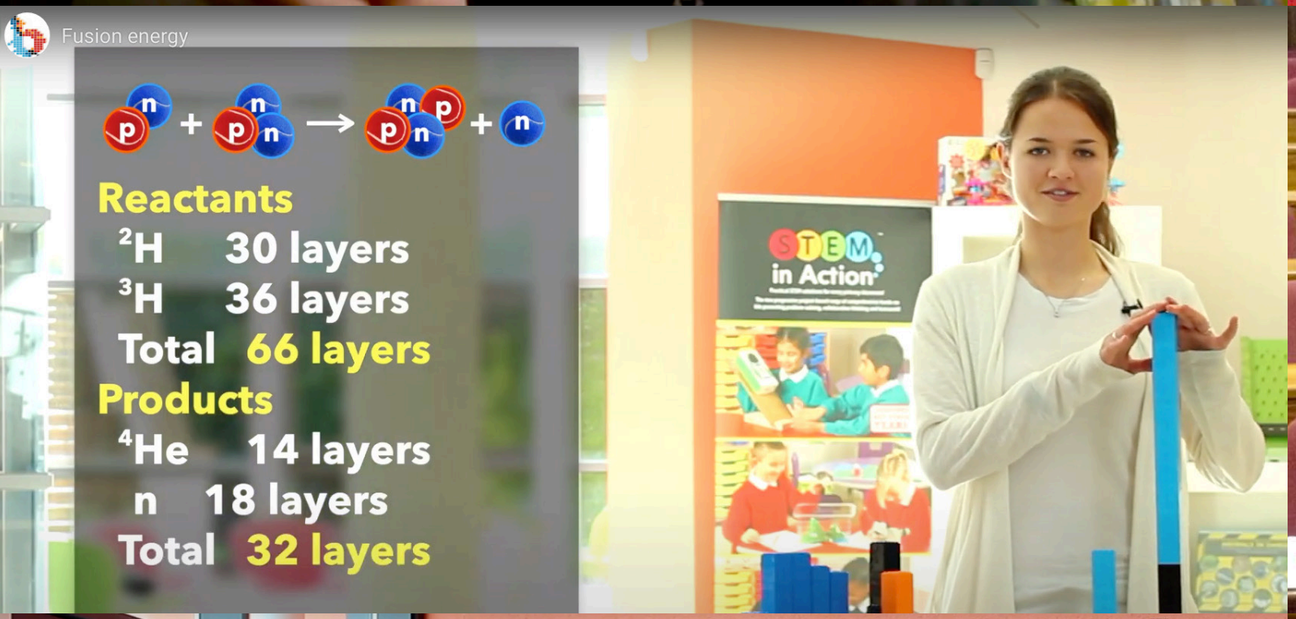

Fusion energy
Reactants
²H 30 layers
³H 36 layers
Total 66 layers
Products
⁴He 14 layers
n 18 layers
Total 32 layers
STEM in Action

2 Evaluation Methodology

The evaluation approach consisted of the following methodologies, summarised below:

- Review of evaluation evidence from students, undergraduates, teachers and members of the public; including funding bids, financial inputs and ResearchFish data.
- In-depth interviews with: Binding Blocks staff (2), Collaborators (2), HEIs (12) , Students (18), KICK-START interns (2), Secondary School (1) and the Science Technologies Facilities Council (STFC) Particle and Nuclear Physics Outreach Officer.
- Data analysis, and production of draft and final evaluation reports. A separate findings report was produced on the online Nuclear Physics Masterclass. The key findings from that report have been incorporated into this document.

Follow up evaluation is recommended to explore the extent to which these positive outcomes and aspirations are sustained.

Detailed review

The evaluation was carried out between January and November 2020, and consisted of:

- Review and analysis of all extant evaluation data gathered between 2017 and 2020
- Design of additional primary research tools
- Secondary review of three submitted bids to the STFC[28]
- In-depth interviews with Dr Diget (Binding Blocks lead), Katherine Leech and Lindsay Clark (Public Engagement team for the Department of Physics at the University of York)
- Case study interviews with 3 current University of York undergraduates and 2 KICK-START Interns (3-month internships for PhD students)
- Interviews with: Collaborators (2), HEIs (12) , Undergraduate students (18), Secondary School (1) and the Science Technologies Facilities Council (STFC) Particle and Nuclear Physics Outreach Officer
- Evaluation feedback from a sample of 209 young people attending 5 masterclass events[29], and 388 young people taking part in the summer 2020 online masterclass, 18 student volunteers, 22 teachers (from 19 schools) taking part in face to face masterclasses, and a further 16 providing feedback on the online masterclass. Finally, 187 members of the public who attended exhibitions provided feedback[30]
- The independent evaluator observed three of the four live webinars that took place as part of the online masterclass.
- In order to explore the collaborative, inter-disciplinary nature of the Binding Blocks Programme further in-depth interviews took place with:
  - Science Technology Facilities Council (STFC)
  - The Institute of Physics
  - An engaged secondary school piloting the Stuff Stars Are Made Of book with primary school aged pupils
  - 12 online survey responses and interviews with HEI collaborators in the UK and overseas

[28] Bids reviewed in chronological order: 1) STFC Public Engagement Small Award, October 2015, Case for Support 2) Application for External Engagement Award 2015 3) Leadership Fellowships in PE 2018 (1 August 2018) and: PPRP Proposal (April 2020) for a projected total of £90k (£30k direct and £60k in-kind contribution).

[29] Masterclass data was analysed for events held at: York (2019 only), Daresbury (2 events, 2019 only), Birmingham and Surrey.

[30] The most recent being an event held in 2020 at the Institute of Physics (see case study).

Limitations

The evidence base for young people draws on a sample of 209 valid evaluation responses. Inconsistencies in the questions used (particularly at the beginning of the programme) and missing responses means that the base size does vary.

The evaluation findings are representative of this wider group of young people to plus or minus 6.6% (at 95% confidence level). In other words, a finding of 50% of participants, if asked to all 3,000 should give a new result between 43% and 57%. Exhibition feedback is representative of all attendees to plus or minus 7%.

In total, 388 young people completed evaluation feedback after the online Nuclear Physics Masterclass. Student responses from the online survey can be considered (using a 95% confidence interval) to be statistically representative of all 1,150 young people taking part to plus or minus 4%. If we combine the feedback from young people, the total student sample from face-to-face and online masterclasses (597) can be considered (using a 95% confidence interval) as statistically representative of all young people taking part to plus or minus 3.9%.[31]

This independent evaluation does not include substantive feedback from teachers who have been trained with the Binding Blocks programme, then incorporated the learning into their pedagogy. Future evaluations should include this within their methodology to underpin and validate the breadth of significance of the responses from the three interviews with teachers who had subsequently borrowed the kit.

The review of extant evaluation evidence revealed inconsistencies in questions used by different institutions, and variation over time, which reduced the comparability of data sources. It is noted that the ability to ethically track pre- and post-event responses would greatly expand the extent to which the journey of change can be elucidated.

[31] https://www.surveysystem.com/sscalc.htm . At 99% the results are representative to plus or minus 4.9%.

3 Details of the impact

The programme's impact from 2017-2020 is presented using the following three key evaluation questions.[32]

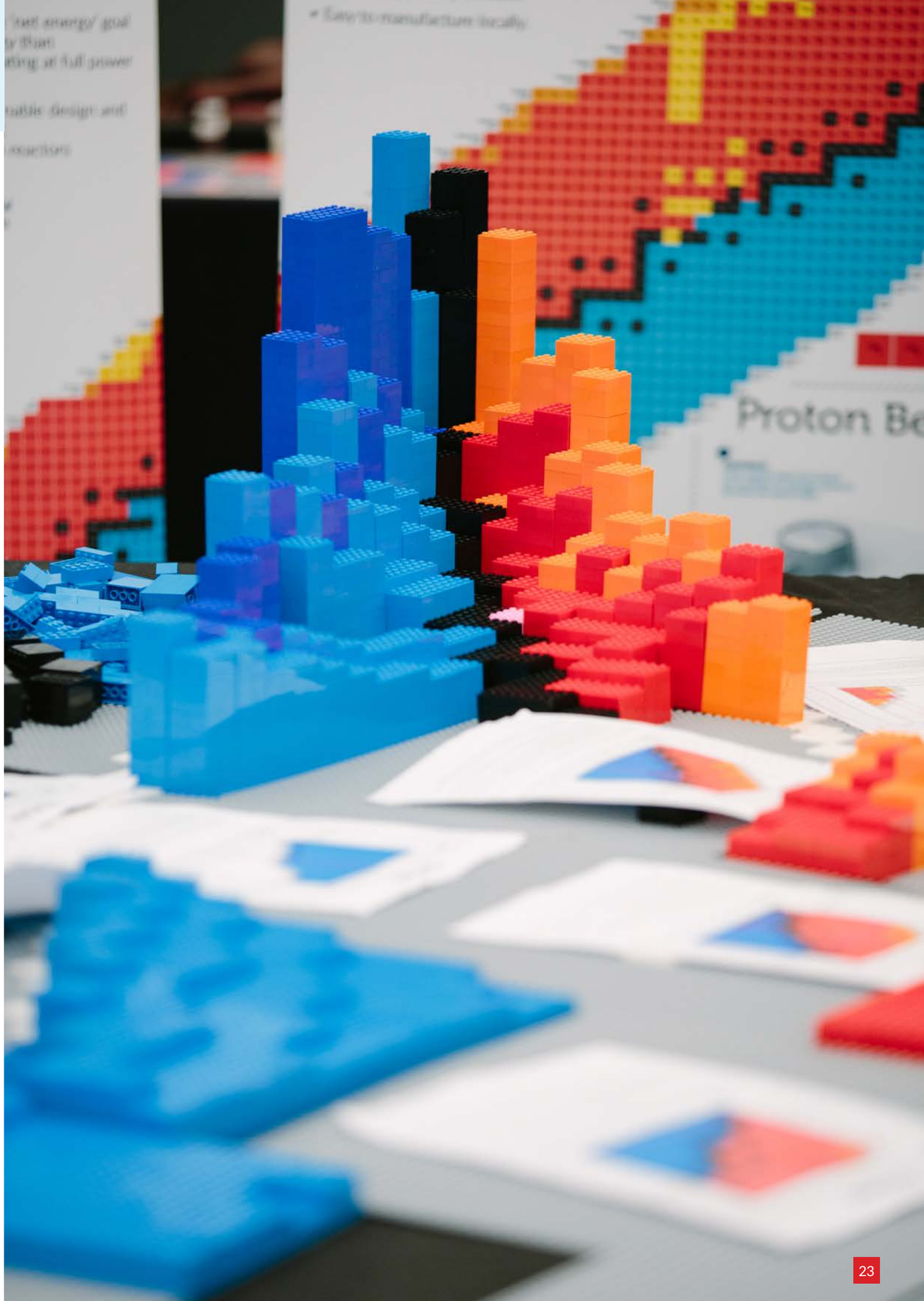
1. Does the Binding Blocks programme inspire, and contribute to students wanting to study physics in the future?
2. Does the Binding Blocks programme play an effective part in teaching the concepts of nuclear physics and developing confidence to talk about the subject with non-specialists?
3. Does the Binding Blocks Programme help to change people's views on nuclear physics?

Within the findings sections, evidence is presented in the following order:

1. Feedback from face-to-face Binding Blocks Nuclear Physics masterclasses[33]
2. Feedback from the online Nuclear Physics masterclass
3. Feedback from other exhibitions and other stakeholders.

[32] https://www.betterevaluation.org/en/rainbow_framework/frame/specify_key_evaluation_questions

[33] Due to inconsistencies in the questions used at earlier masterclasses and missing responses, the sample size does vary from question to question and is referenced in the footnotes. Unless noted in the text, feedback from young people is drawn from face-to-face masterclasses.



4 Key Evaluation Findings

Key Evaluation Question 1: Does Binding Blocks programme inspire, and contribute to students wanting to study physics in the future?

- 58% of young people considered the event had inspired them either 'a lot' (22%) or 'to some extent' (36%). For 13% the event was less inspiring[34]
- 76% gave the nuclear masterclass a rating of either 4 (56%) or 5 out of 5 (where '5' is best')
- 35% said that they are now more likely to study physics in the future, while 57% said there was 'no change'. 8% of participants were less likely to study physics[35]
- Before the masterclass, 66% and 21% respectively were 'definitely' or 'probably' going to university.[36]
- 28% of young people said that they are now more likely to go to university, while for 72% there was 'no change'.[37]

In total, up to 209 young people provided evaluation feedback after taking part in a Binding Blocks programme masterclass.[38] This sample consisted of 64% males, 22% females and 4% other.[39]

Young people were also asked about which, if any, STEM subjects they were considering.

As Figure 1 opposite shows, the largest proportion were thinking about other STEM subjects (40%), as well as non-STEM options (12%).

Physics was also a subject of interest for just over half of those attending – with the majority of this group thinking about studying physics in combination with another subject.[40]

[34] Based on a sample of 189 young people responding.

[35] The perceived difficulty of the masterclass was the main factor underlying this finding. There are 76 missing responses as respondents from Daresbury and Birmingham were not asked this question.

[36] n=164

[37] The wording of the survey does not allow for further interrogation of subject areas of interest. For example, interest in Apprenticeships was only asked at the Daresbury masterclass.

[38] Feedback was obtained immediately or shortly after the Binding Blocks experience. This feedback gives us 'reaction' level feedback (using the Kirkpatrick Model for evaluating the impact of training), and provides intent to behave or act differently in the future. Further evaluation would be required after 6 to 12 months to ascertain to what extent this reaction feedback led to behaviour or attitudinal changes.

[39] N= 135 young people providing an answer. 9% preferred not to say.

[40] The wording of the survey does not allow for further interrogation of subject areas of interest. The apprenticeship question was only asked of students attending the Daresbury masterclass.

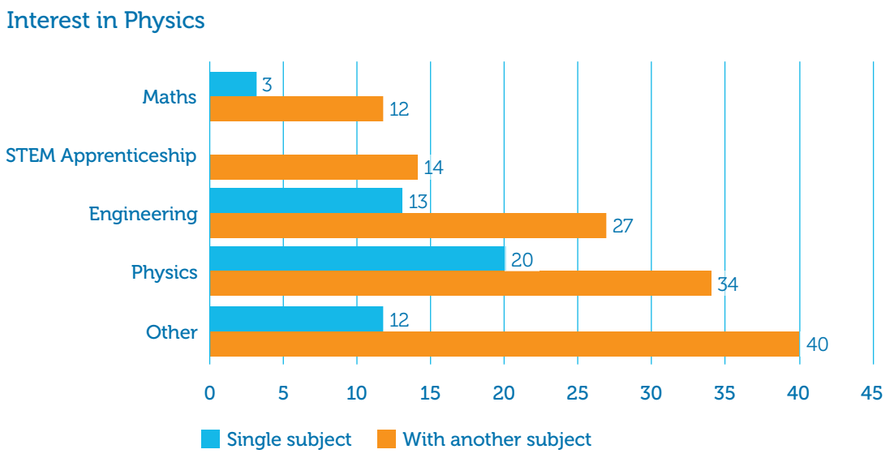


Figure 1: Prior interest in physics

Propensity to go study physics

In total, 35% of students[41] said that they are now more likely to study physics in the future, while for 57% there was 'no change'.

Example 'more likely' responses included.

> "I gained some knowledge that I'd like to build on."
>
> "I already wanted to go to uni, but wasn't convinced I wanted to continue with physics"

'No change' responses included:

> "I'm certain I want to do maths at uni."
>
> "I found the atmosphere and lecturing very interesting, but it hasn't made me more likely to do physics as I am set in how much I want to study physics already."

[41] n=133 responses (as this question was not asked at the Daresbury or Birmingham events).

In total, 8% said that they were less likely to study physics in the future. Analysis of the responses of this subgroup showed that the main factors were

- Lack of interest in physics or nuclear physics
- The perceived difficulty of the masterclass

Example responses include:

> "I want to study other sciences at university, and I don't think physics is the right one for me."
>
> "Looks and feels like I wouldn't understand what I'm doing."
>
> "Go to university: I selected 'no change' because I need to go to university to get the job I want. This session just provided some insight about what university is like. Study physics in the future: I selected 'less likely' because there is too much to memorise."
>
> "[Nuclear physics] is a lot harder and has more depth to it than I thought."

Propensity to go to university

Before the masterclass, 66% and 21% respectively were 'definitely' or 'probably' going to university.[42]

Overall, 28% of students said that they are now more likely to go to university, 72% said there was 'no change'. No participants were less likely to go to want to go into higher education.

Case study 1

Student A attended a masterclass in 2018. He is now studying a Physics and Maths integrated master's degree at York.

"My recollection of the Binding Blocks masterclass is being confused! We were not told much before, and we hadn't done nuclear at college, so it was all new.

I remember doing the LEGO® map, but most of us had no idea of why we were doing it, until the end of the day. We did it anyway. We got clear instructions and figured we'd understand eventually. Then a few lessons afterwards, we did physics processes and then it all made sense; fission and fusion, and energy levels. We'd used the LEGO® blocks to show energy processes.

It definitely helped with doing nuclear physics with the exams, I have an associative memory, so I am sure we had an exam question on energy levels so I could relate to the training. All of us loved the LEGO®, so it was fun, but not childish.

The LEGO® was memorable, but it was taking the time and figuring it out that made it stand out. As we didn't understand it, we had to really discuss it, and think why we thought something was going on. Doing it physically helped it to stick. I remember it as the LEGO day."

[42] n=164

Gender[43]

Physics, as with other STEM subjects, has longstanding asymmetry in take up between genders. The Institute of Physics observes that

"For more than 25 years, there has been very little change in the proportion of girls studying physics post-16. Only around 20% of students progressing on to A-level have been girls, despite similar success between the genders in previous qualifications in physics and science."[44]

In total, 22% of young people completing an evaluation questionnaire were female. Analysis by gender shows that females were more likely to report positive affective outcomes as a result of their Binding Blocks programme experience. The smaller number of females taking part were more likely than males to have their minds changed 'a lot' or a 'great deal' (43% compared to 33% for males).[45]

Other studies on STEM and gender have shown that 'relatability' is important; connecting STEM subjects to real-world examples, tapping into girls' creativity, providing encouragement, and building confidence through successfully completing challenges.[46] There are examples of relatability in the examples given by female Binding Blocks programme students.

Case study 2

As a result of Binding Blocks programme, female participant B was more likely to consider university and to choose physics.

"I realised that physics could open doors to many careers I hadn't linked to nuclear physics. I learnt how to apply the nuclear landscape to questions and how cancer treatments can be adjusted to be less damaging."

The only suggestion she made was to make the event a bit shorter.

Other examples included:

> "I already thought that nuclear physics is a cutting-edge field but today has given me an insight into the real work done by scientists to advance it further and made me really excited for the future."
>
> "I thought nuclear physics would be boring and something I wasn't into. But doing the astrophysics side, as well as the two lectures made me see that there are different types of nuclear physics."
>
> "I now understand it more so it doesn't sound as 'out there' and sounds like something I could study."

[43] This analysis was based on 170 valid responses. This total includes eight by students with other genders giving feedback and 14 who elected not to disclose.

[44] Source: Institute of Physics. https://www.iop.org/education/teacher/support/girls_physics/page_41593.html#gref

[45] They were also more likely to say their views had not altered (13% compared to 6% of males).

[46] See for example: Microsoft (2018) https://news.microsoft.com/features/why-do-girls-lose-interest-in-stem-new-research-has-some-answers-and-what-we-can-do-about-it/. Queen Mary's London PRiSE Pilot Evaluation Report (2017) https://www.qmul.ac.uk/spa/outreach/in-school/school-activities/research-in-schools/evaluation/ and Institute of Physics (2018) https://www.iop.org/education/teacher/support/girls_physics/reports-and-research/file_68898.pdf

However, while females were slightly more likely to say they were likely to go to university as a result (32% female, 30% male), they were comparatively less likely to be more inclined to study physics (36% for females, 45% for males).[47]

Example responses from females who were more likely to study physics point to an increased awareness of the breadth and uses of the subject.

> **"Already wanted to go to university, and I'm now more interested in medical physics."**
>
> **"Students have helped me understand what courses are like and difference between an astrophysics course and physics with astrophysics."**

Overall ratings (figure 2) show that the event received strong ratings by both male and female attendees. It is worth recording that out of all 206 participants answering this question, only one rated the Masterclass as 1 out of 5.

Overall rating by gender(%)

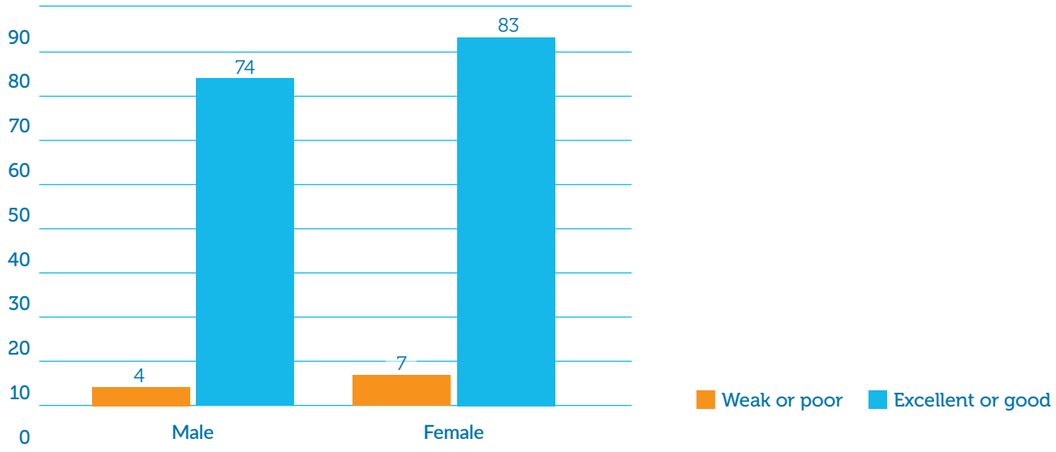


Figure 2: Overall rating by gender[48]

Interestingly, males were more than twice as likely to give the event overall a 3 out of 5 rating (the middle value).

[47] The reasons for this response would require further qualitative research to explore. It is suggested that many of the females attending were already planning to study physics. By increasing awareness of the diverse applications of nuclear physics, it perhaps gave some attendees an additional incentive. The wording of the question used asks about likelihood of studying 'physics' and not 'nuclear physics', which may also be a contributory factor to the finding.

[48] n=148

Location

Further analysis also shows that the degree to which views on nuclear physics were changed varied by location. Young people in Birmingham then York were more likely to agree the event had changed their views, and those in Daresbury then Surrey the least.

By comparison, young people in Daresbury were the least likely to give the event a good rating (62%)[49] followed by 75% of Surrey attendees, 79% of York 2019 delegates and 83% of those attending the masterclasses in London (2020). The most positive response, by location, came from Birmingham (a shorter event), where 95% of young people rated it as 4 or 5 out of 5.

Effectiveness at delivering the concepts of nuclear physics

There is variation between teacher's perceived efficacy of delivering the concepts of nuclear physics to students, the Binding Blocks masterclass considered most effective, and the Hot CNO workshop the least. (Figure 3).

Effectiveness in delivering the concepts of nuclear physics to students (%)

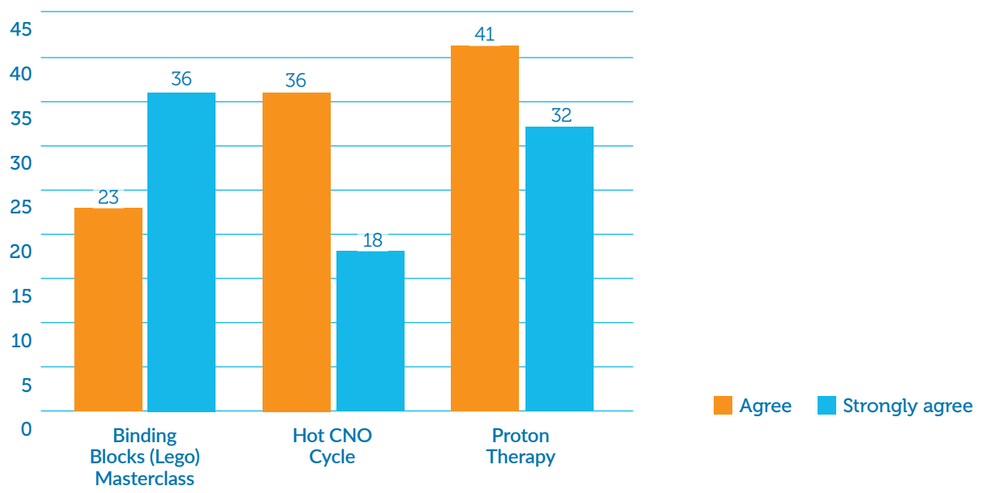


Figure 3: Teacher rating of the effectiveness of the different masterclasses in delivering the concepts of nuclear physics to students

There is a relationship between enjoyment and learning. Masterclass sessions that were enjoyed the most – e.g., Binding Blocks programme (enjoyed a lot by 63%) – provided the highest proportion of students saying they had also learnt a lot (56%). Further analysis reveals that lower ratings were more prevalent in 2018, and following refinements in the format, overall ratings improved in 2019.

[49] Further analysis shows that while half of the schools attending in 2018 and 2019 were from low participation in HE areas, with higher than average proportions of students eligible for free schools meals, students were no more likely to say the sessions were too hard than in other locations. It is perhaps significant that less than half of those attending the two 2018 events felt involved or inspired.

Level of difficulty

Figure 4 below shows students' assessment of the difficulty of the different Masterclass workshops.

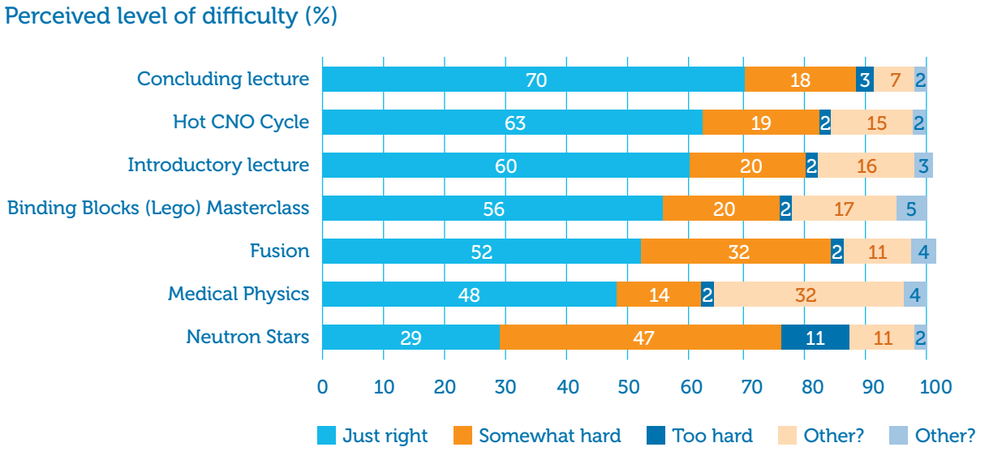


Figure 4: Masterclasses: Perceived level of difficulty[50]

With the exception of the neutron stars and medical physics workshops, the majority of students considered the level of difficulty to be 'just right'. More felt the workshops to be 'somewhat hard' than 'somewhat easy' (with just one exception, the medical physics computer lab workshop).[51]

Further analysis shows that those who found the difficulty to be 'just right', 'somewhat easy' or 'somewhat hard', were more likely to rate the masterclass as either with a 4 or 5 out of 5 (where 5 is 'the best'), and those who found the content either 'too easy' or 'too hard' more likely to rate the event overall as a 2 or 3 out of 5.

Analysis by gender highlighted differences by gender in the following workshops:

- The Neutron Stars computer lab revealed gender differences: 42% of females felt the difficulty was 'just right', compared with 24% of males. 21% of males thought it was too hard compared to no females.
- Females also appear to find that the Fusion task was pitched at the right level (69% of females compared to 49% of males). 36% of males thought it was somewhat hard compared to 23% of females.
- For Medical Physics, more females found it 'somewhat easy' (50% compared with 30% males) while males were more likely to have found it 'somewhat hard' (20% of males compared to no females).

[50] The base size varies from 50 to 144 depending on the number of young people taking part in particular workshops. Care should be taken when interpreting the significance of the findings as a result.

[51] The feedback form does not ask why students found a workshop easy or difficult. Clues can be found in wider feedback, for example one student learned 'a lot' but found the content 'somewhat hard' said "Kind of information overload. A tad. But I did like the variety."

Case study 3: Engagement officer case study

Heather Campbell is the Public Engagement and Outreach Manager for the Department of Physics at the University of Surrey.

"Engagement work for me is more engaging than the research side. It's having the excitement of sharing science with other people, especially cutting-edge research.

I discovered Binding Blocks via Elizabeth Cunningham at STFC who is also based at Surrey. At the training event in York I was really impressed by the physical representation of things they are hard to grasp. It is very different to looking at it, very hands on. The training was run as if we were the students.

Using Binding Blocks doubled the numbers we could include at each event, from 20 to 40. This allows us to reach out to new schools, or to more students per school. We spend 2 hours on Binding Blocks, including an introduction, then the actual building. There is no one person delivering – its co-delivered with the PhD students.

While Binding Blocks doesn't overtly attract or target females into STEM (Heather's passion), with masterclasses typically attended by a small number of females, the programme does help us to build on relationships developed through the Shattering Stereotypes programme.[52]

Because of the Shattering Stereotypes experience (offered to Yr. 8s) it is hoped that females will be more likely to get involved with the Nuclear Physics Masterclass when they reach A level. Some of the Yr. 12 mentors may also participate.

Teachers have to come with the students. Although it's not badged as CPD, I've seen how they get reengaged on exciting things. They then go back to schools and build it in. Unfortunately, some of the training I've seen offered on BB was only taken up by private schools.

In the current COVID-19 infused climate – programmes like Binding Blocks are more, not less important. Scientists are not being portrayed in the best way in the media. Our motivation at Surrey is altruistic, it's about the science not attracting students. Our attendees are local, but they tend to travel nearer to London to go to university."

Phill Day (Public Engagement Manager, Daresbury Laboratory) agrees:

"Young people do sometimes question the motivation for doing the masterclasses. They get to see people like them, different faces, diverse accents, and organisations collaborating together."

As the Binding Blocks Programme evolves, and takes the masterclass format online, academics in Surrey are keen to be involved.

"We think it is great for students to see the collaboration between different universities and specialisms."

[52] https://www.sepnet.ac.uk/outreach/schools/shatteringstereotypes/

Language of nuclear physics

The table below shows, in descending order the most common responses from a word association exercise, completed by young people before and after the Binding Blocks programme workshop.

Pre-masterclass	Number	%	Post-masterclass	Number	%
Fusion	66	7	Decay	53	6
Fission	57	6	Fusion	32	4
Radiation	49	5	Energy	24	3
Energy	35	4	Fission	22	3
Nucleus	34	3	Nucleus	22	3
Decay	26	3	Plasma	21	2
Atom	25	3	Proton	19	2
Nuclear	24	2	Alpha	17	2
Atoms	21	2	Neutron	17	2
Particles	19	2	Beta	16	2
Total	**997**		**Total**	**859**[53]	

The table suggests that young people are developing their understanding of the concepts of the concepts and lexicon of nuclear physics. Compared to their responses on arrival, young people connected more afterwards to content linked to 'decay' and 'energy', and increasingly likely to consider the role of particles, rather than simply atoms. In the words of one participant *"It's much more than radiation and fission."*

Raising awareness of the vast span of the subject, and how the different specialism support and interact with one another was seen by one of the KICK-START interns to be the key challenge for Binding Blocks and the nuclear physics community.

> **"The curriculum teaches the subject in bubbles, with limited time and budget. It's about how can we help that? Teachers don't have time to keep up with all the latest research. Kids are learning in order to learn about the world, so how can we work together as an education community to build this bigger picture?"**

[53] The lower post masterclass total is explained by some school groups having to leave early and so not completing the final questionnaire.

Online Nuclear Physics Masterclass

While the term transformative is over-used, it is arguably the best description for feedback such as:

> **"Honestly, before this course, I had viewed nuclear physics as a fairly limited physics speciality based on what I had learned in my exam classes. This course completely changed my view on this: I have learned how much nuclear physics can offer: from nuclear astrophysics (which I particularly found interesting) to its fascinating use in medicine. It is truly a versatile and poignant field of research."**

Prior to the event, 91% were intending to go to university. Afterwards, 43% nevertheless agreed that the online Nuclear Physics Masterclass made them more likely go to university.

Overall, 49% of student participants[54] (hereafter students) were planning to study physics, while 38% replied 'maybe'.

Females were more like to state 'maybe' (42%) compared to males (35%).

Over two-thirds of all students (68%) considered that, as a result of the Nuclear Physics Masterclass, they were more likely to study physics in the future, with females more likely to report this. (Figure 5 on the next page).

Has the Nuclear Physics Masterclass made you more or less likely to study physics in the future?

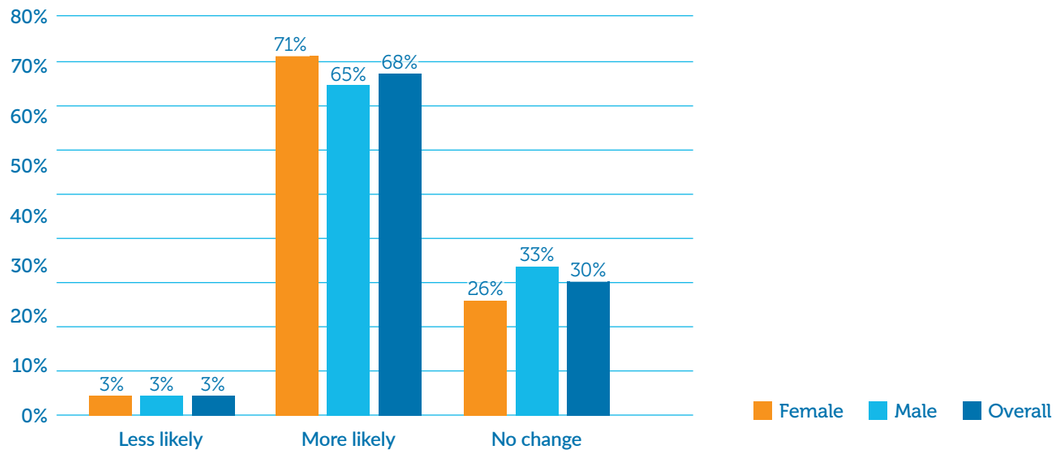


Figure 5: Online participants' interest in studying physics in the future

N=329

[54] N = 329

Analysis of a further 308 open responses to the question *'Has the Nuclear Physics Masterclass made you more or less likely to study Physics in the future?'* provided showed some clear themes. Most striking was the group of just under a third, who, as a result of the masterclasses were now planning to study physics at university.[55]

> **"The inspiring course offering really made me re-evaluate my options to consider studying physics".** (Online participant)

Among those already decided on higher education, reassurance was gained that an online mode of training delivery was one they could engage with.

> **"In this course, I saw so many professors and researchers who have a huge passion for their research as well as their jobs. It makes me really look forward to experiencing the life in university. Also, all those contents about physics are so interesting!"** (Online participant)

The evaluation responses demonstrate that minds and preconceptions about nuclear physics have been challenged and changed.

> **"I have got more insight into what studying physics at university would be like now and have found it more interesting than expected." (Online participant)**
>
> **"I didn't have much of an idea what nuclear physics really entailed until completing this masterclass, but having completed it I am really fascinated by it. It's amazing how things so small can make such fundamental differences to everything, really."** (Online participant)

Based on the open responses, students who were already interested in physics generally had their interest affirmed and built on.

> **"I was not as interested in the nuclear side of physics, but this course has totally changed that, I'm really passionate and engaged now."** (Online participant)

[55] This group provided 90 open responses from a total of 308 (29%)

Gender and Ethnicity

Further analysis by gender shows females were more likely to strongly agree that they were inspired by the Online Nuclear Physics masterclass (63%) compared to their male peers (45%).

In turn, females were also more likely to strongly agree they were inspired to learn more about nuclear physics (65% compared to 50%). Women were more than twice as likely to give a 10/ 10 response to the question 'would you recommend the masterclass to your peers' (39% compared to 17%).

Females from a BAME background[56] were more likely than other females and the overall sample to say they were inspired by the masterclass. It may merit further investigation to explore the finding that as a result of the online Nuclear Masterclass, BAME females were more likely to want to study physics in the future (81% compared to 67% for non BAME females and 68% for the sample as a whole.)

Counterfactual

To test the extent to which the outcomes reported might have been achieved by other means (for example self-study) students were asked *'If you hadn't taken part in the Nuclear Physics Masterclass how likely is it that you would have learned about nuclear physics anyway?'*

Overall, 52% said it was likely or very likely, while 32% considered it was unlikely or very unlikely.

Females were also more likely to say that, in the absence of this online masterclass, they were unlikely or very unlikely to have found out about Nuclear Physics by some other means (37% compared to 28% of males)

International Perspectives

The Binding Blocks programme has also inspired and supported nuclear physicists around the world.

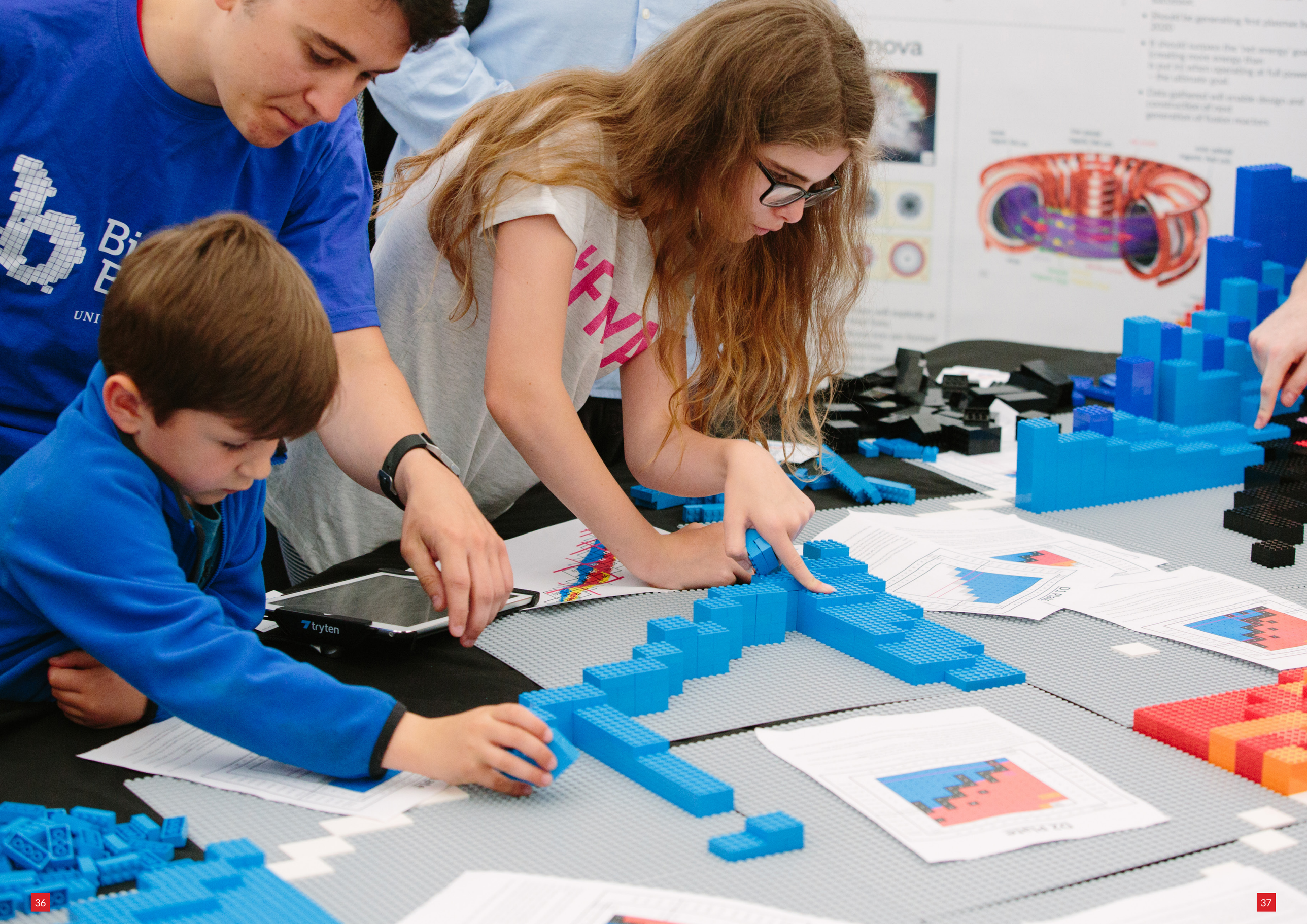
In total 26 partnerships[57] have been developed through Binding Blocks programme including the Universities of Birmingham, Glasgow and Liverpool, as well as STFC Daresbury Laboratory. These are institutions with a strong record of knowledge exchange with a focus on nuclear physics.

Collaborations have been fostered overseas, with researchers and teachers in Canada, Singapore and South Africa. Student volunteers who have taken part in Binding Blocks masterclasses are now pursuing their careers around the world.

Host institutions are at different stages of maturity in nuclear physics. For example, a March 2020 event was held at an institution with a developing nuclear physics department at Sheffield Hallam University. York's team, led by Dr Christian Diget and Dr Alessandro Pastore, supports other institutions to initially deliver smaller events. Staff receive training prior to delivering masterclass events.

[56] N=48. This group were also less likely to say, without the masterclass, they would probably have done something comparable.

[57] Please see Appendix 2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Training is carried out to develop skills and build capacity at other institutions. *"The leadership aspect is very portable,"* says Dr Diget, and the Binding Blocks programme team have also trained staff and PhD students in Botswana and South Africa (the source of the feedback that follows).

> **"For me personally, as a student, the collaboration could not have happened at a better time. Through the collaboration, students from the Department of Physics at University of Zululand attended 3 weeks training at the University of York in September 2018.[58] Three more students have attended the training at the beginning of this year (2020) – this has not only benefited the students, but it has also benefited the Department of Physics in UZ."** (International partner)

The following case study from Canada highlights the transferability of the impact.

Case study 4: Jesse Abney, Public Programmes Manager at TRIUMF[59] says:

"We most valued the element of surprise. That LEGO® Blocks could be the element of such interest to successfully intrigue any age into a collaboration to construct the chart of nuclides. Secondly, it reinforces simple to grasp learning outcomes through the physical interactions of the Hot CNO cycle and crafted gameplay mechanics.

As an institution, the completeness of the project has made the idea of adoption easy. This alone has reduced most barriers to entry. A true evangelist, Dr. Diget's support has covered anything that's been missed. In TRIUMF's case this has been funds to acquire the equipment and resources to manage those assets.

We have ideated on several applications since being introduced to this program. One involves depicting the chart of nuclides in the lab's landscape architecture design to create a permanent space for community engagement utilizing the Binding Blocks programme Hot CNO cycle game mechanics.

To me this idea transcends the constraint of the block to perform, while retaining the benefits of the interactions that still teach.

LEGO® is a unique equaliser. It's my strong belief these invite participants from every age along a path of understanding. The structure of the lessons allow interaction on some level with the information. The gameplay leads to fun, and that makes the learning outcomes sticky."

[58] Binding Blocks and public engagement were one part of a wider science training programme.

[59] Canada's particle accelerator centre (https://fiveyearplan.triumf.ca/ @triumflab)

Key Evaluation Question 2: Does Binding Blocks programme play an effective part in teaching the concepts of nuclear physics concepts and developing confidence to talk about the subject with non-specialists?

> "Through teacher training, we will reach at least 300 [secondary school] teachers, who will – within the scope of the Fellowship – deliver the material to an additional 2,000 students." Aspiration set out for the Binding Blocks programme in a Fellowship proposal to the STFC (2018)

This section on the evaluation report draws on feedback from 18 student volunteers and 22 teachers about the pedagogical benefits of engaging with Binding Blocks programme .

The National STEM Learning centre have been involved in both sets of training because, as well as teacher training (their main remit), they are also the national lead on the STEM Ambassador programme.

Jointly with the National STEM Learning Centre (York, UK), the Binding Blocks programme has implemented c.10 teacher training courses, attended by c.20-40 teachers per course.[60]

- Teacher feedback highlights that the training was engaging (95% agreed or strongly agree), and informative (41% strongly agreed their knowledge of nuclear physics had improved, 96% agreed to at least some extent)
- 77% of teachers agreed or agreed strongly that the Binding Blocks programme approach is relevant to the curriculum they teach. 59% agreed or agree strongly that the Binding Blocks programme workshop would be effective in delivering the concepts of nuclear physics to their students.

Teachers reported that the Binding Blocks programme training increased their confidence about nuclear physics. The training equipped them with new approaches to enhance their pedagogy that were engaging and interesting for their students.[61] Teachers valued being able to access a fully formed methodology that could be adapted to meet the age, group size and interests of students. Feedback suggests that the smaller groups of students engaged more effectively with the kit. There was limited feedback on areas for improvement, but suggestions were:

> **"Needs greater differentiation according to age group."**
>
> **"Building Blocks is most relevant to the AQA Physics A-level in Year 13. Possibly most relevant to them between September and January."[62]**

[60] Whilst some courses were specifically for teachers of A-level Physics (or equivalent), other courses were broader with both Primary and Secondary (11-16) teachers present.

[61] Follow up feedback from 3 teachers who had borrowed the kit all strongly agreed that 'Participants found the Binding Blocks activity engaging' and 'Participants learned something doing the activity.'

[62] The timing of masterclasses was also highlighted as important by partners, aligning, as far as if practicable shortly before nuclear physics is covered in the curriculum.

The table below presents exemplar outcomes reported by teachers following their Binding Blocks programme experience.

Improved pedagogy (skills and resources)	"I have more practical and engaging activities to use with students as opposed to basic two-dimensional graphs and questions." "It is more accessible when drawing analogies and demonstrating concepts." "Tools that were used are effective in engaging students turning abstract content into enjoyable learning activities."
Improved confidence and inspiration	"Feel more confident in delivering particle physics." "This has been excellent and has inspired ideas for a themed stem club." "Lots of new ideas to help teach a range of ages."

Reach

Three schools gave feedback when returning a borrowed kit (as part of a pilot schools LEGO® loan scheme). Teachers delivered over 12 hours of teaching using the kit to 67 students (an average of 22 per class), primarily at Key Stage 5.

> **"Pupils found it engaging. Younger classes I teach all pointed it out which led to quick discussions about isotopes and fusion etc."**
>
> **"Students really liked the fact it was made out of LEGO®, and enjoyed watching the Binding Blocks programme YouTube videos of the larger model."**

Further analysis suggests, albeit from a small sample, that teachers who found the training engaging, and relevant to the curriculum they teach were more likely to have had their views changed.

Analysis of feedback on Binding Blocks programme workshops (figures 6 and 7 on the next page) shows that, on average, 7 in 10 teachers agreed or agreed strongly that the individual workshops were effective vehicles for delivering the concepts of nuclear physics.

The Binding Blocks programme team may wish to reflect on the variation in results below from a cohort of teachers.[63]

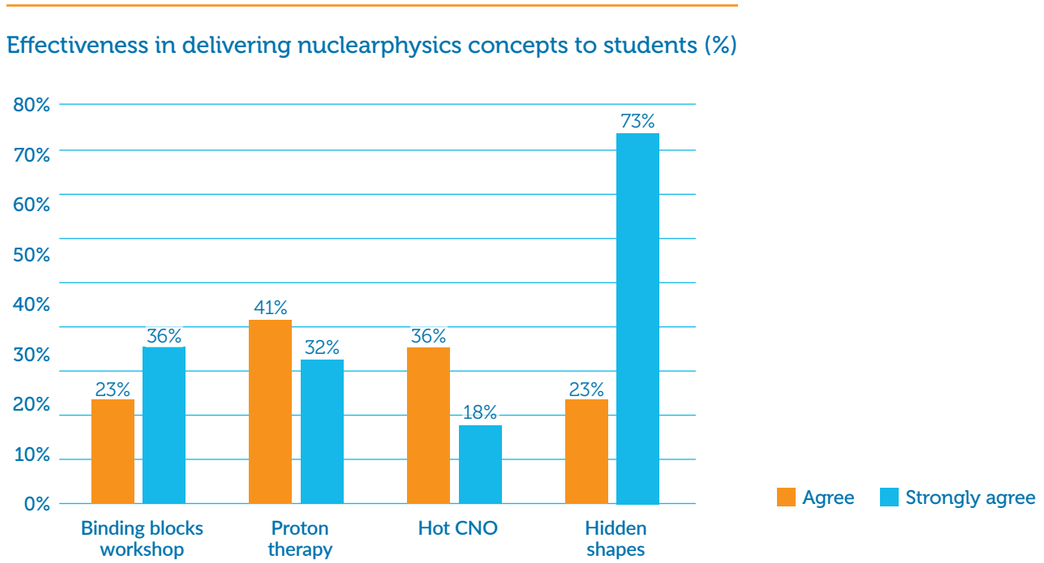


Figure 6: Effectiveness in delivering nuclear physics concepts to students (% of teachers)

[63] The Hidden Shapes workshop was designed by the University of Glasgow and is the only one designed to be appropriate for younger students.

Figure 7 below shows that, on average, 7 in 10 teachers would be interested in delivering future sessions based on the Binding Blocks programme approach.[64]

The positive feedback to the Hidden Shapes workshop highlights strong potential demand from teachers of students prior to A-level (or equivalent).[65]

Interest in future delivery

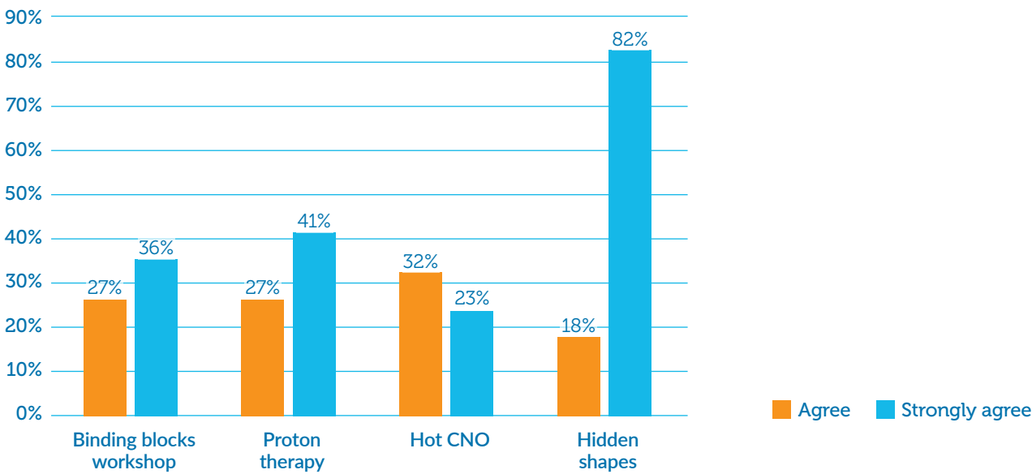


Figure 7: Interest in future delivery (% of teachers)

Student volunteer feedback

The Binding Blocks masterclasses and exhibitions are supported by student volunteers (both undergraduate and post-graduate), who receive training prior to supporting events.

- This sample of 18 student volunteers had, between them, taken part in at least 50 activities (public exhibitions, nuclear masterclasses), including the training session, an average of 5 activities each. Six of the volunteers responding had also taken part in an internship connected to the programme.
- 78% of volunteers (14 of 18) said that the training received had either met or exceeded their expectations and all rated the training as either good (13 of 17) or excellent (4).
- 66% (12 of 18) felt that their involvement in Binding Blocks programme had increased their knowledge of the applications of nuclear physics to a significant extent.[66] 61% (11 of the 18) were also interested in finding out more about nuclear physics.

[64] The reasons underpinning these assessments is not known. Understanding whether these views are representative, and to what degree the mode of delivery and level of difficulty were factors would perhaps be valuable in guiding the future development of the programme. This proportion also broadly aligns with 82% of teachers opting in for further communication about Binding Blocks.

[65] In England, Key Stage 2 and Key Stage 3.

[66] Responding with either a 4 or a 5 out of 5.

- 83% (15 out of 18)[67] considered the training to have helped them to be either very confident or confident in communicating their nuclear physics knowledge to non-specialists, for example school students or the general public. The same proportion agreed that the training had helped develop their confidence more generally.
- As a result of the training, 78% (14 of 18) of the students expressed a desire to get involved in further STEM activities with young people. Half of this sample expressed a wish to find out more about teaching.

In the next section is a case study from the perspective of three KICK-START interns, followed by the experience of a host institution. 3-month PhD internships for public-engagement (open to all UK Nuclear Physics students) with a funded PhD extension to complement, rather than replace, research.

Case study 5: KICK-START Interns Case study

This case study brings together the views of two KICK-START interns.

York connections

The interns first encountered the Binding Blocks Programme while studying at York, but not all were able to get actively involved.

"I was already involved in Binding Blocks when doing my masters in York. It was a fascinating way of getting us involved. It was a lot of fun. Teachers being trained were so engaged, but it was quite an investment in time."

Talking about the subject with others

The two KICK-START interns interviewed were unanimous on the importance of being able to talk to non-specialists about their subject.

"I enjoy talking about the physics. Binding Blocks is my way to share my enthusiasm with others. I mostly enjoy talking to older people, 30-40s as they already have an interest and are catching up on missed opportunities from their own schooling.

Other forms of outreach I've seen are generally much narrower. Binding Blocks has this visual chart, it's so striking. It's very adaptable, I think it works best from age 14 up as it does require prior knowledge. It's the main tool for the nuclear physics community.

The curriculum teaches the subject in bubbles, with limited time and budget. It's about how can we help that? Teachers don't have time to keep up with all the latest research. Kids are learning in order to learn about the world, so how can we work together as an education community to build this bigger picture?

"At school pupils aren't really exposed to the fun stuff. Physics gets a bad reputation. With Binding Blocks, students, teachers and adults can talk to experts in their subjects."

The internship provided a safe space to try and develop outreach skills, without displacing their studies.

"What made it great was not losing time on the PhD, and it's paid."

By sharing their knowledge and enthusiasm, KICK START interns also derived benefits for themselves.

[67] The sample of volunteers consisted of 7 undergraduates, 5 graduates who have left university, 2 currently completing a PhD in a nuclear subject, 2 doing another STEM PhD and 1 who has finished their PhD and is no longer in a university setting.

"Katherine Leech came to York at start of my 2nd year, she created a real impetus – suddenly things happened! Telescopes, radioactivity, European Researchers Night, more and more. I always like being able to share: it's a fundamental part of your role. A researcher needs to be able to explain, its morally important. It tied so well together. As I was getting excited learning about research, I was able to share this excitement with others.

You get lots from it as well. A member of my family was having radiotherapy, and at one event I was asked about how this works by someone else about to start treatment. We talked about how the radiation scatters. I spent ages with her, it felt like kismet."

Suggested improvements

Suggested improvements were in the assessment of progress, the potential extension of the online offer and extending the physical reach of Binding Blocks

"Create a user-friendly interface for the online offer."

"A VR 3d virtual rendering of the chart."

"Develop a way of assessing progress by the students, perhaps using 'Mentimeter[68]' real time responses….creating a new way of assessing them against STFC goals – what needs working on. Themes, what's not set."

"Target underserved communities – traditionally those with lower access to HE."

Recommending to others

I would encourage people to pursue it. Internships can be challenging, but some institutes like post docs to have this outreach experience. These internships bring new students into the field

"I love it when you get the 'wide eyed response' and the realisation that a light bulb has gone on, and a connection has been made."

[68] https://www.mentimeter.com/

Case study *6*: KICK-START host case study

Rachel Montgomery is a research fellow at the University of Glasgow nuclear physics group. She has been very actively involved with the Binding Blocks project, including hosting a KICK-START internship and running teacher training events.

"We were successful with an STFC Spark Award and enrolled a PhD student as a KICk-START intern. It was bit daunting at first, never having been PI on the grant but Christian was extremely helpful.

We run 1 or 2 events Binding Blocks events per year, as half day activities for schools.

I met regularly with our KICK-START intern as he arranged outreach and logistics for the INPC conference. He came up with the concept, researched the physics and put together the materials, the conference poster for example.

It was really rewarding as I could see him develop; nervous at first then he gained confidence.

After the INPC we wanted to continue and use the material again. There isn't much public engagement in Scotland – so we thought it would be good to create kits for schools. One of the activities is a 'build your own particle scattering kit containing a ramp and targets. I was particularly impressed with the online Nuclear Physics Masterclasses, and with the online offer we could open it up to more Scottish schools. Working with the STEM ambassadors office – we have the potential to bring the materials to all regions of Scotland…

In Scotland, Binding Blocks links very well to curriculum.

I really enjoyed the Binding Blocks training seeing the subject with fresh eyes."

Training outcomes

The most useful aspects of training are illustrated in the table below. Students reported a combination of cognitive (learning and knowledge), skills and affective outcomes (attitude change – increased confidence from taking part).

Outcome	Exemplar comments
Confidence and communication	"Helping with my confidence in Public Speaking and Engagement with others." "Building confidence around people."
Knowledge	"The building of and getting to grips with the Binding Blocks programme chart." "Learning to demonstrate how to use the model to apply physics to everyday life." "Learning how to adapt concepts to explain a complex topic to a diverse audience."
Experience	"An opportunity to go through the whole workshop piece and 'receive' the session." "Getting familiar with the different aspects of the chart, and how to communicate these." "Being talked through features of Binding Blocks programme by academics."
Skills	"The ability to adapt a delivery style to a range of audiences." "Writing academic papers." "It's mostly just been public engagement skills for me." "Project Management, Organisation, Coordination, Public Speaking, IT, Time Management."

One of the key outcomes from the training was to develop the confidence and skills to communicate about nuclear physics to non-specialists.[69]

Volunteers were asked why they felt this was important to them at this stage in their learning/ career.

Their comments show that effective communication can support physicists to continue to carry out their research, attract the next generation of physicists, and more broadly, develop the science literacy among the population and build trust in science (aspects of science capital).[70]

[69] In effect, anyone who has not completed at least an A level in physics.

[70] Of the 8 aspects of Science capital, Binding Blocks can be shown to support: Science literacy, knowledge, participation in and out of school learning activities, and knowledge about the transferability of Science. Source: https://transformingpractice.sciencemuseum.org.uk/eight-dimensions/.

Exemplar comments are shown below:

> **"Being able to convey information to people to allow them to understand and form an opinion on a subject, rather than being told what's correct or not."**
>
> **"It is important to communicate to non-specialists so that more people can become interested in physics."**
>
> **"Publicly funded work needs public approval; we have to be able to explain what we do. Research isn't complete until the result has been communicated."**
>
> **"In the context of a growing political distrust of experts and in a culture of "fake news" the ability to clearly communicate sound scientific concepts is more pressing than ever before."**

Finally, feedback from researchers involved in the delivery of the online Nuclear Physics Masterclass affirmed that the process had been effective, with early involvement and clear communication.

> **"It went pretty well, given the circumstances, offering students a clear and professional view. The preparation started early. I was involved and clear about my role. It felt like a seamless experience."** (University collaborator)

Key Evaluation Question 3: Does the Binding Blocks programme help to change people's views on nuclear physics?

Young people were asked whether the Binding Blocks programme event had changed their views on nuclear physics.[71]

The chart below shows that, for 35% of young people, the Binding Blocks programme changed their views on nuclear physics either 'a lot' or 'a great deal', and 40% 'a moderate amount'.

View on nuclear physics, the extent of change (%)

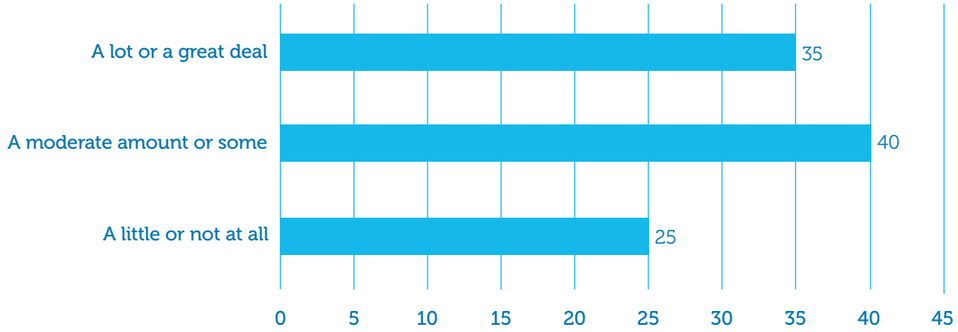


Figure 8: Views of nuclear physics (% of young people)[72]

Females were more likely to report that their views had changed about nuclear physics.

Case Study 7

Male student C attending, along with five others, a nuclear masterclass at York University, where he is now studying.

By his own admission, *"already sold on physics"*, he nevertheless enjoyed the challenge of getting to grips with nuclear physics.

"There was a buzz in the room. At each mini briefing, they asked if we had been taught this yet, then explained at our level. You didn't need the maths to understand the full explanation. I came out knowing a lot more than I came in, for example on astronomy.

It was very interactive, more so than other events. That engagement makes it interesting.

I don't just like remembering facts, I like to figure things out for myself. I can then cope with whatever I am thrown. With that knowledge comes the ability to think.

There was a pattern to Binding Blocks programme , I like patterns."

[71] It is an assumption inherent in the methodology that students held an opinion about the subject.
[72] n=209

The table below shows exemplar responses from young people answering why their views on nuclear physics had been changed. To ensure the voices of young people are present in the evaluation, a variety of quotations are included.

Where opinions and mindsets had changed, it was apparent that the breadth of the subject, the range of applications, and the opportunity to get into detail were important. The findings also show that students can gain benefits; either cognitive (knowledge)[73], or affective (attitude shift) regardless of their views going into the event.

Extent views were changed:		
'A great deal'	**'Some'**	**'A little'**
"I wasn't aware of how much was involved in nuclear physics until this."	*"I learned that we are significantly closer to harnessing nuclear fusion that I thought."*	*"I know more about it now and prefer it more to how I did."*
"I found some areas that were very interesting as previously I had not found this area interesting at all"	*"I realise that it could open doors to many careers I hadn't linked to nuclear physics."*	*"Opened my eyes to new concepts."*
"I didn't know people still discover new isotopes"	*"I now know a bit more information based around nuclear science and why it is used."*	*"I thought we knew a lot more than we actually do."*
"Shown variety of applications of nuclear physics."	*"I thought nuclear physics would be boring and something I wasn't into. But doing the astrophysics side, as well as the two lectures made me see that there are different types of nuclear physics."*	*"Made it not just about bombs and radiation."*
"Now I've seen more in depth, I've seen how interesting and linked it is to the whole of physics"	*"I already thought that nuclear physics is a cutting-edge field but today has given me an insight into the real work done by scientists to advance it further and made me really excited for the future."*	*"It hasn't really changed my opinion as I already found it interesting."*
"It made me have a better understanding of what doing physics at uni is like."	*"Initially I was unaware of the specific applications of Nuclear physics in astrophysics. This masterclass has definitely given me an insight into these."*	*"LEGO® can represent physics"*
"Learnt about medical physics and the ideas behind CT scans."	*"Got a broader view of the different deep fields of study in physics."*	*"It's a bit more interesting now."*
"It's definitely not as hard as it looks, it can be understood easily if paid enough attention towards."		*"I used to think nuclear physics was just bang, bang Hiroshima."*
"I realise now the benefits greatly outweigh the risks."		*"I liked it, I still like it, but a bit more."*
"It has made me have a much deeper understanding of just how far nuclear physics really goes, even into things you wouldn't expect."		
"It sounds really fun and I've learnt there's a lot of chemistry involved."		

[73] This triangulates with coding completed by the University of York that shows 'knowledge' as one of the top outcomes from the event.

Teachers

In total, 100% of a sample of 22 teachers[74] agreed that the workshops had changed their view on how they could communicate nuclear physics.

Creating awareness and interest in nuclear physics is arguably a pre-requisite to developing the next generation of highly qualified scientists, researchers and teachers. STFC have supported the Binding Blocks team throughout their development. Dr Diget's Public Engagement fellowship (2018) created the capacity to galvanize the nuclear physics outreach community around the programme and its versatile modular format.

> **"The multifaceted approach appeals. Inspirational physics masterclasses are important, but I liked the public engagement aspects too. With the STEM Learning Centre on campus, the University of York is uniquely positioned to get tearchers interested in the subject."** Dr Elizabeth Cunningham. Particle and Nuclear Physics Outreach Officer at STFC

STFC recognise that the programme creates valuable learning and experience for undergraduates.

Going forward, primary school children are seen to be the age group most open to engaging with the subject, whether through hands-on workshops or stories.

Looking from this perspective, the Binding Blocks Programme is helping not only changing established views, but positively introducing nuclear physics to a young audience.

The example below comes from Canada, followed by a UK based case study.

> **"The Binding Blocks programme events have benefited the community of the city of Guelph, and vice versa the events have placed the Department of Physics and the University of Guelph in peoples' minds as a source of engaging activities, and for kids as an option for a future career."** (International partner)

[74] Attending training in June 2019, from 21 different primary and secondary schools and colleges.

Case study 8: Reaching younger audiences

"The Stuff Stars are Made Of" was written by Dr Adam Tuff, a former York PhD student and collaborator with Dr Diget.

Tuff's book, with an initial print run of 1,500 (paid for by the University of York using additional STFC funding), presents the Binding Blocks programme to a Key Stage 2 audience. The copies held by the University of York will be presented to 60 primary schools.

Having studied at York, Adam now works at Kromek[75] in County Durham developing gamma-ray and neutron radiation detectors, and manages a team of staff scientists. He advocates taking part to students to boost their employability.

"Set yourself apart from the crowd! Extra-curricular opportunities for outreach, work experience and internships, and science clubs available to you during your student life are invaluable experiences and give you the edge when applying for jobs."

In 2010, while completing his PhD at York, Adam met Christian Diget, forming a link with the university that has endured. The shared passion for communicating nuclear physics to young people also began at this time.

"One of the problems of communicating nuclear physics was that it is hard to recreate a demonstration safely. We entered a competition, and came up with two complementary tasks; We had brilliant feedback".[76]

Following the realisation that no one had done a science book in the style of the Gruffalo, together with illustrator Kieran Gates, Tuff wrote the book in a concentrated 3-4-month period. *"The key was at what level to pitch the physics, which is what the Binding Blocks programme team now do very well."* The first batch of 50 was self-published in 2015. By 2018, there was an appetite for more copies, and York supported Adam to publish a larger number, 1500.[77]

Adam has observed and supported Binding Blocks programme since the beginning. The connection between elements, *"the building blocks of our existence"* and LEGO® is well made, says Adam. *"Kids realise they can do this, and it sparks their imaginations."*

Dr Tuff attended a 2020 Institute of Physics Binding Blocks programme event.

"There were activities pitched for the ages attending. It appealed to future video game programmers, builders, artists and physicists. It felt unrestricted and creative."

The Binding Blocks programme and The Stuff Stars Are Made Of work effectively together.

"The Binding Blocks programme can lead into events with the book, then convey those ideas with the LEGO®. The book makes them receptive. It's the symbiosis of story and physics. The book is the introduction… and the end, well the story is not finished. Its only limited by your imagination, which is the universal appeal of science."

To date, 120 copies of the book have been distributed to 50 schools, for example handed out to 70 teachers as part of a primary school CPD event.

[75] https://www.kromek.com/careers/physics-careers/adam-tuff/

[76] Another early, and enduring inspiration were the comic strips of Randall Munroe, in his XKCD publication, which also used blocks as a metaphor to visualise radiation.

[77] Another early, and enduring inspiration were the comic strips of Randall Munroe, in his XKCD publication, which also used blocks as a metaphor to visualise radiation.

Dr Tuff and Dr Diget share a common end goal of propagating their resources as teaching tools. A key learning point is to make materials accessible online, drawing on gaming applications, as well as resources for parents and teachers. The internet is also a more fluid space where physics can be accessible to all genders.

"Online, the barriers between boys' and girls' toys are crumbling."

The example below shows, using one primary school in Stoke on Trent[78], how the book can be used to fire the imaginations of young people. Having received five physical copies of the book, it was read online to the entire primary school (by the deputy head and literacy lead).

The video received 115 views, and positive feedback from parents and young people.

"I liked Big Blue as the main character. I liked the repetition of his name. It is good for anyone interested in space, young or old, so it doesn't matter if there are words you don't understand because you just love space. I think a nebula would look good on the front cover too in the background." (Young person)

The session inspired young people to think about subjects for a potential follow up:

- How does everything orbit the Sun?
- Why are planets different: like why does Saturn have rings?
- Sky/atmosphere- why does it change from blue to black?
- How do we know- the scientists who find this out?

The Science, Creative Curriculum and Careers Lead used the book to engage in follow up conversations with Year 6 pupils being home schooled during the COVID-19 lockdown. Going forward she sees great potential for initiatives like Binding Blocks within the primary science curriculum. Plans were in place to develop a space and literature theme for the school's science week in October 2020.

"The science curriculum has plenty of scope to go with what children are interested in. There is room to make it child led. Use it to pose some big questions."

[78] The connection to the Binding Blocks Programme came via www.scienceacrossthecity.co.uk. "We have 70 schools in Stoke and have developed a model of distributed school to school support with enthusiastic leaders that are willing to go above and beyond in connecting all children in the city to great science."

Online Nuclear Physics Masterclasses

Four in five students taking part in the online Nuclear Physics Masterclass had their views on the subject changed either 'a great deal' or 'to some extent'.

37% of students said that the Nuclear Physics Masterclass had changed their views on nuclear physics 'a great deal'. 43% said it had changed their views to 'some' extent. 12% said it had changed their views 'a little' and 8% said 'not at all'. There were subtle differences by gender, although the extent to which the masterclasses had made a great deal of difference was consistent.

Has the Nuclear Physics Masterclass changed your views on Nuclear Physics?(%)

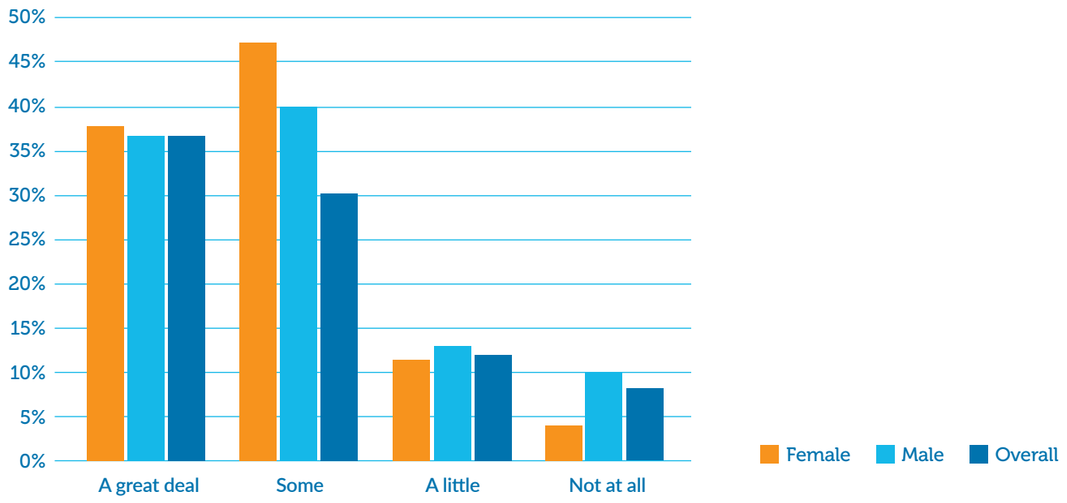


Figure 9: Views of nuclear physics (% of young people taking part online)[79]

Further analysis was carried out on 266 open responses which expanded on how views of nuclear physics have changed.

"While I already loved physics, the course deepened my understanding of the field, giving me some of the tools needed to work with the kind of figures used. It was as though I had a 2D picture of nuclear physics, and the Nuclear Masterclass made it 3D." (Online participant)

Responses to the question "Has the Nuclear Physics Masterclass changed your views on nuclear physics? If yes, how?" identified three key themes:

1. Increased awareness of the real-world applications of nuclear physics (100 – 38%)
2. New or increased knowledge (97 – 36%)
3. ncreased awareness of the breadth of nuclear physics – (50 – 19%))

The table on the next page provides example responses.

[79] n=388

Increased awareness of the real-world applications of nuclear physics	New or increased knowledge	Breadth and connections
"I am now aware that there is a lot more to just the famous equation E=mc2, and understand in more detail the large potential of nuclear fusion and fission, and creating stars on our Earth to enhance energy production on a scale we have never seen before. The day that we can source consistent energy from these processes will truly change the world and save its energy crisis." *"I am much more interested in it now as I can really see the applications it has."*	*"The masterclass has provided a level of detail which I feel was lacking from the nuclear physics I have studied so far. In providing explanations for why events happen (as opposed to stating that they happen) I think that I developed a greater understanding of the principles underpinning nuclear physics."* *"I've realised how in-depth physics can be, how far-spread it is in our society and world. Secondary school taught me the basics, now I want to explore the future, thanks to this Masterclass!"*	*"To be quite frank I did not know much on nuclear physics, so the masterclass taught me a lot about the lifestyle of physicists as well as the research and developments/ discoveries in physics. I really do love how 'no two days are the same' and being amongst others who are very interested and invested in the research would also be encouraging. The content of each topic was very interesting so I learnt much, much more then I could have hoped for, I got the most out of this experience".* *"Made me more optimistic about the area, showing how cutting edge a field it is. Also, it has definitely helped me change my view on nuclear fusion -- it seems actually viable, and not so far-fetched/sci-fi."*

The real-world applications, and particularly the applications in medicine were new for many and appealed.

For GCSE level students moving to A level, the masterclass proved different to their previous experience of physics.

> **"I used to see physics as boring, but now I don't. It's a lot more exciting than anything we learned in school so far."**(Online participant)

Reflecting on the online Nuclear Physics Masterclass, 96% of students rated the masterclass as 4 or 5 out of 5 (where 5 is the best rating).

Further analysis shows that males were more likely (60% compared to 50%) to judge the content to be 'just right' while females were more likely to consider it 'somewhat difficult' (44% compared to 33%).

Figure 10 below shows consistently positive ratings, with 99% agreeing that the content was interesting and that they learnt something new. Almost nine in 10 (89%) felt inspired by the Nuclear Masterclass, and interested in learning more about the subject.

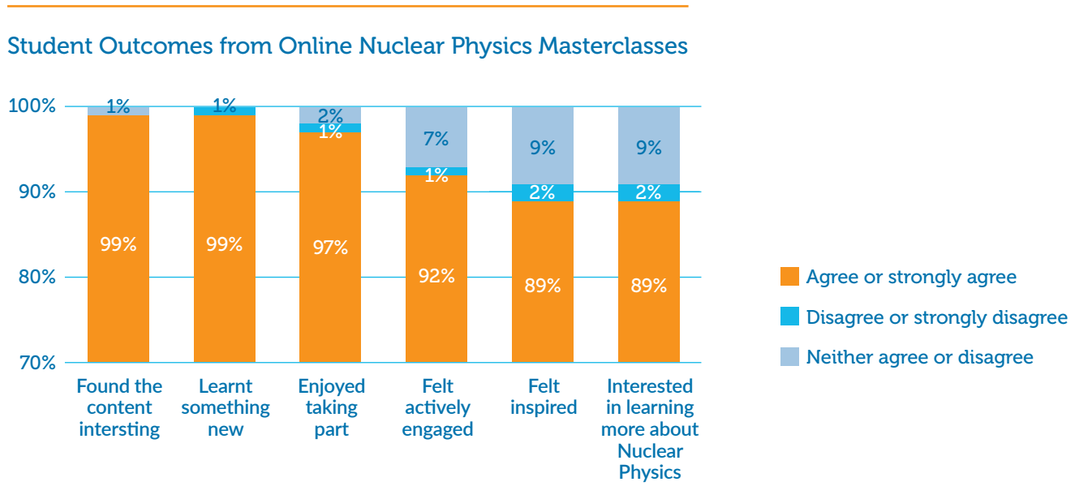


Figure 10: Student outcomes from online nuclear physics masterclasses[80]

Difficulty, challenge and enjoyment

> **"Each day you have new challenges, and you can normally solve it. That is really nice."** Mikhail Bashkanov, Lecturer at the University of York

Analysis of the questions relating to the difficulty of the Nuclear Physics Masterclass reveals that most students thought the level of content was 'just right' (57%) and 38% considered the content 'somewhat difficult'. [81]

> **"I didn't find anything "too difficult" just the right amount of challenging."** (Online participant)

The masterclass succeeded in striking a delicate balance between creating challenge and delivering relevant content in accessible and engaging ways. Participants provided detailed feedback of aspects that, for them, were either too easy or difficult.

[80] n=333

[81] % thought it was too difficult. 5% 'somewhat easy' and <1% 'too easy'.

> **"Although I had already heard about stellar nucleosynthesis and medical physics, it was very interesting completing the modules on these subjects and gaining a true understanding of them. I was also very interested to not just memorise formulae but also to understand and use them in the course. I also enjoyed the interaction with the lecturers and being able to ask questions."** (Online participant)

It was apparent that while the level of difficulty was appropriate for the majority, there were others who required additional resources, explanation and support.[82]

The maths element was most commonly highlighted – although for the majority the level of challenge was appropriate.[83]

> **"I found the maths too difficult for me personally because I haven't learnt some of the concepts that were in the maths activities especially the Isaac physics questions.**
>
> **Some of the maths tasks did take quite a lot of time to actually get the right answer (some stuff on Isaac physics) but overall, it was all doable."** (Online participant)

The support structure established received positive feedback, and reduced drop out.

> **"The last two weeks were very difficult and some of the questions I was very unsure of but after spending time reading through the resources and the Q&A, I was able to complete them."** (Online participant)

Nuclear medicine was most commonly singled out as the most enjoyable, followed by fusion.

> **"The medical physics was the area that felt the most interactive. It was very interesting as I did not know in great detail how physics is used in medicine."** (Online participant)
>
> **"The fusion content and the theory behind the binding energy and what effects it with the magic numbers being very interesting in explaining phenomena in our universe we observe."** (Online participant)

[82] Participants who considered the masterclasses 'somewhat difficult' overall provided more examples than those who judged the content to be 'about right' or 'somewhat easy'.

[83] Unsurprisingly, coping with the mathematics was more challenging for some of the younger, GCSE level or equivalent participants. Overseas students also reported unfamiliarity with some of the concepts.

Two stakeholders offered divergent opinions on whether the masterclasses would have been improved by offering them to a narrower and older age group.

> **"I feel it would be better aimed at a specific group rather than GCSE to those just finished with A levels. Although the course says only GCSE knowledge is assumed there were times that higher concepts were thrown about…"** (Teacher)

> **"…Thank you for not having it age restricted. This has been a useful insight into A level Physics and beyond, to university and career options if she were to carry on following this interest."** (Parent)

Access

Three-quarters of students (76%) said they could access all of the resources, while 26% could not. For reasons unknown, females were less likely to be able to access all of the resources (31%, compared to 22% of males).

Looking forward, most students said they would take part in either online courses or face-to-face courses (73%). One in five (21%) would prefer online courses while 6% would rather take part in face-to-face courses in the future.

Suggested Improvements

Participants provided useful feedback on how the online masterclasses could be refined. It is important to stress that, uncommonly, the majority of comments were very positive[84], and provide a strong basis for the further development of this pilot approach.

> **"I think that my experience was perfect, I learned loads and the quality of materials was of the level I expected, and more! I especially liked watching the videos made by university students, which I thought were easy to understand and very interesting, and it was good to get a student's perspective on the topics covered."** (Online participant)

[84] As an example, 57 out of 58 final comments were positive in tone.

There were 107 suggestions for improvement.[85] After coding, the top two themes were:

- More interactive

> **"I found the practical exercises like the modelling was by far the best as you learnt without getting bored just reading a lot. So, I think the more practical work the better, but you already had a pretty good balance of it this time."** (Online participant)

- Followed by 'More'…content, explanation, detail, resources, masterclasses'. These comments naturally reflected the likes and interests of the participants.

> **"Worked examples when equations are introduced so it is easier for less advanced participants to understand them."** (Online participant)

Net Promoter Score (NPS)

Overall, 52% of students could be seen as 'promoters' and 7% as 'detractors'. This provides a NPS of 45.[86] This should be considered a 'good to excellent' score.[87]

Females gave a NPS of 56 compared to 37 for males ('excellent' and 'good' ratings respectively).

Feedback from teachers

- In total 15 teachers provided evaluation feedback.
- All 15 rated the Online Nuclear Physics Masterclass as either 4 or 5 out of 5 (where 5 is the best rating).
- 60% learned 'a lot' from the masterclass, and 40% learned 'some'.

Like their student counterparts, teachers praised the masterclass – highlighting the well-judged level of difficulty, organisation and engaging delivery.

- 80% (12 out of 15) said the level of difficulty was 'just right'.

[85] As an example, 57 out of 58 final comments were positive in tone.

[86] https://delighted.com/nps-calculator

[87] Based on the global NPS standards, any score above 0 is considered 'good'. 50 and above is 'excellent' while 70 and above is considered 'world class'. https://delighted.com/nps-calculator

> **"Unlike some open access courses, I felt like this course gave a good amount of challenge and was pitched at the right level - it made me stop and think but the questions were answerable in a reasonable amount of time. In addition, I really appreciated the effort put in to making the course up to date and relevant with some exciting bits in it about current research."** (Online teacher participant)

> **"The level at which it was pitched was perfect for my Y12 students. I found it a great primer for studying many of the topics we will cover in Y13, but also gave them extra depth of they wanted it."** (Online teacher participant)

Pedagogy

- Two thirds of the teachers (67% or 10 / 15) considered that the online Nuclear Physics Masterclass had improved their confidence to teach nuclear physics modules 'a lot'.

The masterclass informed the teacher's pedagogy – helping them to connect the curriculum to real life applications.

> **"I loved watching the presentations during the webinars and seeing how GCSE and A-level physics is applied in research and the wider world. The topics became very real and gave me a lot more to talk about when I teach it."** (Online teacher participant)

> **"Very structured and accessible. I came away with some great ideas on how to teach certain topics."** (Online teacher participant)

- 60% said that the content 'very well' supported the taught curriculum with 40% saying it supported it 'a fair amount'.
- 67% said they used the Nuclear Masterclass with their students, and all would like to access the masterclass resources in the future.[88]
- Without the masterclass, teachers would most likely have generated content for themselves on nuclear physics, another part of physics or one of the other STEM subjects. It is unlikely that teachers would have referred their students to another online masterclass, particularly on Nuclear Physics.[89]

[88] It is not clear from the survey if this answer reflects actual or intended behaviour. Teachers were mainly supporting students in Year 12 and 13.

[89] Only 1 teacher would have found another nuclear physics masterclass and 2 another online STEM course.

There were suggestions from Scottish colleagues about how it could be further refined for that audience and for relevance to the curriculum.

> **"We cover nuclear physics and radiation, so the material is relevant and up to date**
>
> **Week 1 gave an excellent overview which is highly relevant to the core of the A-level. Week 2 was fantastic for astrophysics. Week 3 was applicable to both GCSE and A-Level and provided some excellent context that I feel I can use for enriching my teaching. Week 4 was excellent for the AQA medical physics (and I loved playing with the simulation). Overall, it was exactly what I wanted – taking me slightly above where I need to be in terms of subject knowledge which will enable me to enrich the curriculum and answer those tricky questions."** (Teacher)

> **"The Scottish Higher Physics curriculum is fairly light on the maths associated with the nuclear content; …I certainly hope this masterclass runs again and I would definitely encourage more of my pupils to get involved but I would probably produce some step-by-step guidance for each of the maths parts; I know this was done to some extent on the webpage but 'over-communication' is definitely the way for less confident pupils."** (Teacher)

Exhibition feedback from the general public[90]

Alongside, and in addition to the masterclass events, exhibitions have been also been held, which utilise the Binding Blocks programme theme to engage visitors of all ages with nuclear physics.

As an illustration, the INPC conference was conceived thus:

> **"At the INPC conference, the community came in for a public engagement day with talks and hands on stuff. We deliberately tried to make it look it like a story. First you saw the Binding Blocks LEGO®, so we talked about the nuclide chart and radioactive processes. Then, when you had that understanding you went upstairs. The exhibits walked you through the different areas… 'This is how it used in medical physics', 'This is how the detectors work with scattering'. It showed how the processes flowed together."**

[90] Based on a sample of 95 visitors to 2 exhibitions.

Attendees at exhibitions identified the following outcomes, together with example feedback. Feedback can be seen to align well with the four criteria for assessing excellence in exhibitions: 'comfort', 'engagement', 'reinforcement' and 'meaningfulness'.[91]

- Combined exhibition feedback shows that 84% of participants 'agreed or strongly agreed' that the exhibition was interesting, across all age ranges[92]
- 86% of participants 'agreed or strongly agreed' that they learnt something.[93]
- 71% of participants 'agreed or strongly agreed' that they would be interested in learning more about physics.

Feedback from those attending the Institute of Physics family day included:

> **"Uses kids' language of LEGO® and Minecraft and quiz. And hands on experiments."**
>
> **"It has many fun activities and the information from the helpers is very useful."**
>
> **"I enjoyed it so much as it was really fun and educational. Really beneficial for all ages."**

[91] Beverly Serrell's 'Framework for assessing excellence', 2006. https://eldivanmuseologico.files.wordpress.com/2018/05/346e0exh_fall07_assessingexcellenceinexhibitions-threeapproaches_teller.pdf

[92] Base for 'interest' and the 'interest in learning more about physics' was n=178

[93] Base n=180. The smaller sample of over 65s were less likely to report this.

Case study 9: Institute of Physics Exhibition

The Binding Blocks programme team developed and led a 4-week pop up exhibition and programme of masterclasses, a family day, events and talks during February 2020. Under the banner, 'Building the Universe, One Block at a Time', the London events engaged a wide range of audiences: from members of the Institute of Physics, sixth form students, to families and younger children from Islington, and Harringay. The event supports the Institute's Unlocking the Future 2020-2024 strategy to instigate meaningful contact between the public and a physics-based public event.[94]

Imogen Small, Public Engagement Officer at the Institute of Physics says:

"Having the exhibition in our space downstairs was brilliant for engaging our members who are all physicists. The nuclear chart itself is stunning, really cool."

The LEGO® chart was the centrepiece, and around the walls were 17 information panels taking the visitor from first principles through to applications. Digital content, including the Minecraft version of Binding Blocks programme and Quantum 3[95], was available throughout.

Evaluation data from the event reveals that 65% of those attending the exhibition at the Institute of Physics in 2020 agreed that it had changed their minds about nuclear physics.[96] More females than males attending the IoP exhibition said it had changed their mind about the subject (69% compared to 61%). 60% attending would recommend it, while 14% could be seen as detractors. This gives a 'net promoter score' of 46, which is a 'good' rating.[97]

From an IoP standpoint, the tailored masterclasses and family days were the most successful aspects, engaging and well attended. Extra activities, storytelling and support enabled young people and their families to engage at a level they felt comfortable with. 250-350 people attended, from a diverse set of backgrounds.

"All of our events have the potential to reach families with low science capital."

The exhibition was seen to be 'really accessible', although navigating the fine line between engaging expert members of the Institute of Physics on one hand and being accessible and not intimidating for families coming in from the street with no prior knowledge of nuclear physics was perhaps beyond what is reasonable to expect of any exhibition. The decision to have an explainer in the exhibition through half term week was seen as an effective approach.

The 'double benefit' of the Binding Blocks programme approach is building the confidence and skills of physicists to talk about the subject and their work with non-specialists.

"Enabling physicists to have these conversations is a double benefit of the project. What's the point in finding out something and not sharing it? It's talking to people outside your bubble. If the project helps to make this normal for students…then that can only be a good thing."

In summary: "The exhibition was broadly a success, the events definitely a success. Overall, it's a brilliant project. In my view, the next steps for the team of York will be focusing it further on their intended audiences."

[94] Source: https://www.iop.org/about/strategy#gref

[95] https://gamedev.msu.edu/quantum3/

[96] Based on feedback from a sample of 91 attendees

[97] Based on 90 valid responses. For an explanation of the Net Promoter score, please see: https://www.questionpro.com/blog/nps-considered-good-net-promoter-score/ "Given the NPS range of -100 to +100, a positive score or NPS above 0 is considered "good," +50 is "excellent," and 70+"world-class.".

Feedback from three exhibitions highlighted the following themes:[98]

Engaging	*"We need more of these in Scotland specially to engage young people."* *"Very interesting and fun for everyone."* *"It was pretty good. Informative and interesting without being patronising."*
Created or affirmed interest in nuclear physics	*"We want to know more about nuclear physics.* *"Start teaching from young ages (primary school level)"* *"The event teaches us more about science, physics and chemistry. It's the best event and teaches us about the importance of all the stuff we learnt."*
Appropriate content and educational	*"A very good introduction for non-physicists to the basic ideas of what is behind the huge research facilities for nuclear physics, with simple and home-made means."* *"Very professional and easy to understand"* *"Should be taught more at primary and secondary school"* *"It's a good learning tool"* *"It was a thrilling and educational"* *"I think the teaching methods should be enrolled in schools for students to learn."* *"The project is amazing because it gives a clear visualisation of how elements occur in nature..."* *"Enables maths & science (physics) to be easily understood"*
Relevant	*It was a very good event that can sustain people's life and very intriguing."*

Attendees frequently praised the *"friendly, helpful and informative staff"* – a combination of IoP staff and staff and volunteers from the University of York (who were present during busy periods, which was especially useful).

[98] The INPC conference described on page 40, a February 2020 event at the institute of Physics (case study page 41) and finally, a June 2019 exhibition at the Botswana International University of Science and Technology (BUIST).

5 Towards Longer Term Outcomes

> **"To scale from local to national with national and international impacts."** Dr Diget

From the earliest beginnings in 2015, the team have had an ambition that takes them to 2030. The Binding Blocks programme has the following intended longer-term impacts:

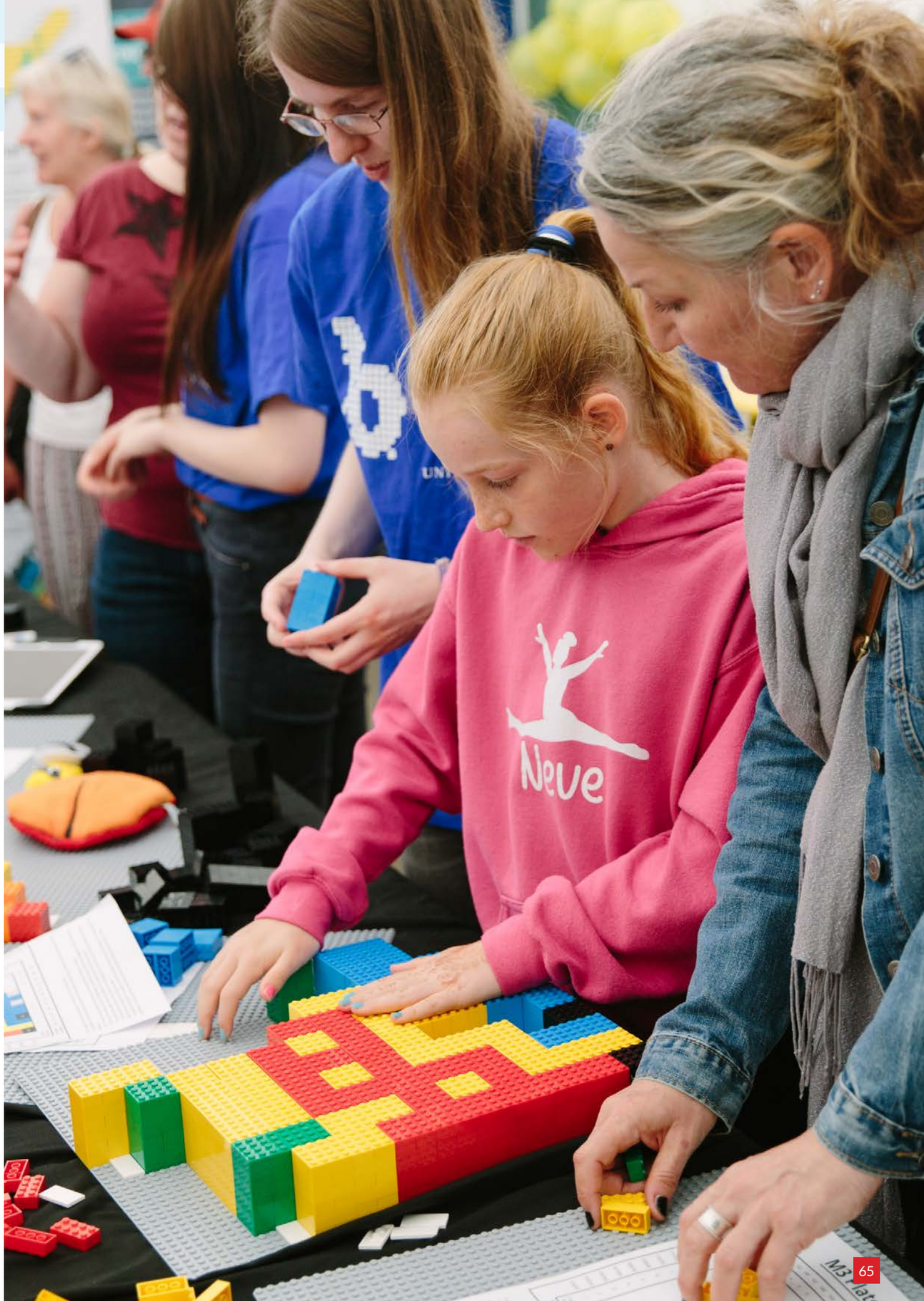
1. Integrate STFC Nuclear Physics into delivery of A-level curriculum and equivalent curricula taught across the UK.
2. Develop a free online course in Nuclear Science to facilitate a scalable delivery of front-line nuclear science with reinforced learning and strong links to STFC nuclear physics research.
3. Lead capacity building in public engagement and a culture change in Higher Education across the UK, with broader societal and international impact.
4. Enhance the profile of and progression routes for public engagement in undergraduate and post-graduate physics in general and advanced nuclear science in particular.

The programme's core audience is currently young people studying A-level physics and above, which includes undergraduates and teachers. Enabling teachers to include the Binding Blocks programme as part of their pedagogy will greatly increase the programme's reach. To achieve the UK's longer-term impacts to create science capital and increase the pipeline of young people entering STEM careers, relies on the inspirational ability of teachers. To date, over 350 teachers have taken part in Binding Blocks programme events or training. Online resources have also been developed, accelerated by the COVID-19 pandemic.

Feedback from teachers, as in the detailed comment below, highlight that while masterclasses are valued and valuable, the difficulties attracting young people to study physics requires a multi-partner, strategic response.

> "Industry/academic involvement is an area I would really like to expand into the physics at school, although what form this takes is always a difficult one. The motivational effects don't tend to last all that long, I suppose when 'reality' comes back the following lesson and they're back doing more calculations or other rather less 'whizz bang' aspects of physics but which are nonetheless needed to get them to be able to pass an exam.
>
> I teach in a somewhat deprived area and getting pupils to pick physics can be a real challenge; other subjects are easier, so taking those subjects, followed by a swift exit from education into a regular supermarket job is a well-worn, easy and popular route.
>
> But there are so many opportunities in engineering and physics which, if better highlighted by me or communicated through some meaningful industry/ university interaction could get far more pupils into genuinely fascinating and worthwhile areas. Such masterclasses are probably a great start, but any other ideas/ ways forward/ collaboration projects I'd be very up for further chats/emails about."

Scaling up Binding Blocks programme from a local to a national face-to-face programme will require both further funding support and additional contributions from partner universities.



6 Success factors

Evaluation evidence and feedback has highlighted the following as key 'building blocks' in the effective delivery of the Binding Blocks programme, aspects that are seen to be working well. There is scope to consider the potential for Binding Blocks to take a more formalised leadership role for public engagement for nuclear physics.

Stakeholder feedback

Feedback from the Institute of Physics event identified the following learning points for the Binding Blocks programme team to reflect on:

- Reflecting on Binding Blocks programme, there is value in events that are free to access and that link into the A level curriculum. Key stage 4 is seen to be much more of a challenge, since it is tightly timetabled and the links with the GCSE curriculum less overt. Greater flexibility exists in Key Stage 2 and 3 to add value, but the adaptations required to the content much greater.
- The exhibition in its raw format is 'neutral informative content' and is enhanced by the presence of an explainer with 'artefacts' (for example a banana to illustrate 'banana equivalent doses' (of radiation)) or activities to stimulate 'situational interest'.
- Future exhibitions should be curated with a clearly defined audience in mind. In its current form it is perhaps rather intimidating for a 'walk in audience' for example.
- The Binding Blocks programme team were seen to have a leadership role to play among the physics community on outreach and engagement activity. It was observed how the team were catalysing the involvement of others, and could therefore be valuable to a range of organisations seeking to engage. The team's potential to coordinate outreach work across university physics departments was seen to be beneficial.

Monitoring and evaluation

The framework is in place to capture reaction to a Binding Blocks programme encounter, but needs to keep pace as the programme evolves. Evidence will also support the rebalancing of resource required to scale up the Binding Blocks programme .

Age details were not gathered as part of the feedback process for masterclasses. As these are increasingly opened up to young students, gathering the ages of attendees will be an important variable to capture.

In order to develop a more nuanced picture of the contribution the Binding Blocks programme is making to the subject choices of undergraduates, the Department of Physics at York could begin tracking how many in the cohort encountered the programme, then ask to what extent (as a percentage) that encounter influenced, or not, their decision to study a) physics and b) at York.

With additional funding, extending the framework to include follow up research after 6-12 months would enable the Binding Blocks programme team to more accurately assess the extent to which mindsets, behaviours and pedagogy is changing, as well as providing a more detailed picture of the reach and application of the school loan LEGO® kits.

Targeted qualitative research with teachers at the end of their training would usefully explore the factors influencing their propensity to use the approach in their own work, while colleagues at the STEM Learning Centre are well placed to advise on extending teacher CPD and curriculum links.

As teachers increasingly use the Binding Blocks programme as part of their teaching, developing monitoring and feedback loops will be necessary in order to efficiently and easily provide a means of tracking the number of students reached and the outcomes for those young people. A suggestion is to develop a virtual community of practice for teachers, and work with this core group to pilot and test emergent tools and evaluation approaches.

7 Conclusions

Does the Binding Blocks programme inspire, and contribute to students wanting to study physics in the future?

While it is true that A-level students represent the vast majority of masterclass participants and are already positively disposed towards physics, their opinions and views on nuclear physics are being positively influenced further by the Binding Blocks programme – particularly by seeing the types of subjects that they could explore at university. Almost three in ten students said they were more likely to go to university as a result.[99] Online Masterclass students consistently reported how the content had enabled them to realise the exciting breadth and potential of physics, which felt different to the curriculum studies at A-level.

The suite of workshops is adaptable, and enhanced by the facilitation skills of the Binding Blocks team and volunteers. The volunteers are gaining subject knowledge, confidence, pedagogical skills and approaches and the desire to continue talking and sharing their interest in nuclear physics with others. The reputations of partner universities are increased by the collaboration and, through trained and paid KICK-START internships for PhD students, there is an increasing cohort of people able to support and lead sessions. York alumni and former interns work across the globe.

This positive encounter with physics can be seen to influence young people's subject choices in higher education. As masterclass students are studying A-level physics and, based on this sampled evidence, already intending for the most part to go to university, the extent of the contribution from any one programme is likely to be small. The timing of interventions can sometimes be more significant than the scale of the programme and it will be interesting to follow up with online Nuclear Masterclass participants; inspired during a national lockdown, to assess how formative that experience turns out to be in their post 18 choices.

Does the Binding Blocks programme play an effective part in teaching the concepts of nuclear physics concepts and developing confidence to talk about the subject with non-specialists?

Student volunteers affirmed the importance of being able to talk about nuclear physics with non-specialists, be it funders, members of the public or others in the academic and research spheres. The Binding Blocks programme provides stimulus in abundance to create interest and discussion, and the team have learned how to adapt the content to the age of their audience. The programme differs from other outreach approaches which typically use a combination of experiments and stage craft to create an audience reaction. The Binding Blocks programme is at once familiar, since it is made of LEGO®, but also novel. Building the kit takes time and perseverance.

Teachers agreed that the programme was aligned to the curriculum and could envisage, to varying degrees, using the concepts from the workshops and the approach as part of their pedagogy. Student volunteers, benefitting from the training which offers a 'dry run' with the kit, talked of increased confidence and the knowledge to deliver the programme to diverse audiences.

The Binding Blocks programme team, and a growing network of university partners in the UK and overseas, have tested and developed their capabilities over nearly 80 events. As a programme it is arguably well positioned as the knowledge leader for the sector on nuclear physics outreach.

[99] 28% of 133 valid responses

The next chapter in the Binding Blocks programme evolution will require new approaches, and efficacy in working through teachers to use the kits or virtual equivalents in a wider variety of settings, and to younger students. The active engagement and support from 'early adopter'[100] teachers will be critical in adapting and refining this more indirect approach to engagement.

Does the Binding Blocks programme help to change people's views on nuclear physics?

This independent evaluation concludes that, based on the feedback from students, volunteers, teachers, members of the public attending exhibitions, and partner organisations, the Binding Blocks programme is making a positive, practical contribution to changing views about nuclear physics.

For a minority, the experience confirms their view that the subject is difficult, but for the majority, Binding Blocks illuminates the potential of the subject both for future research and how different disciplines within the subject collaborate with one another. This is perhaps even more apparent online where it is possible to feature speakers from across the world.

It is not only young minds that are being influenced, but teachers accompanying young people or being trained directly are feeding back positively.

Supporting exhibitions chart the course of the subject and its applications, and are greatly enhanced by the student volunteers who can pose and respond to questions, as well as engaging people with the skilful use of 'artefacts'.

[100] Typically, 12-14% of the total market, in this case, of secondary school physics teachers – totalling 6,642 in 2018-2019 according to DfE statistics. This would provide a target of 900 teachers for Binding Blocks to engage. Sources: https://ondigitalmarketing.com/learn/odm/foundations/5-customer-segments-technology-adoption/ and https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england

8 Recommendations for further research

1. The evaluator would like to present the following five suggestions for further research.
2. Develop a learning community of practice for the Binding Blocks programme practitioners to share learning, and successes, engage in evaluation and pilot new approaches.
3. Commit to extending, in a proportionate manner, the evaluation framework for Binding Blocks programme, in order to develop assessments of the extent and durability of the outcomes created at masterclasses and other events. Standardise the evaluation forms used, their ongoing completion and regular analysis and review.
    a. Based on evaluation feedback to the online masterclass, commission qualitative research with females, both BAME and non BAME, to test the hypothesis that the online format is a more equitable format.
4. Collaborate with the UK Physics community to refine and share the pilot online materials.
5. Assess the feasibility for the Binding Blocks programme to become a hub for people who want to talk about physics, and widening participation.
6. As part of the projected expansion into Key Stages 2 and 3, consider whether the Binding Blocks programme can be aligned to the Children's University Programme, which has been assessed as a 'promising project' by the Education Endowment Fund.[101]

Disclaimer

The information in this independent evaluation report is presented in good faith and is thought to be accurate as of 17th December 2020, however the author cannot accept responsibility for errors or omissions.

[101] The approach uses after school clubs as a vehicle to boost academic attainment. https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/childrens-university/

Appendix 1: Programme Finances

Source	Description	Value
STFC Small Award (2015): LEGO Nuclear Chart - Inspiring Future Physicists	Payment of undergraduates as casual workers for event delivery Travel and transport costs Catering for student training Design and print of materials LEGO® base-plates 3d printed models	£8,000
University of York External Engagement Award (2015):	LEGO® bricks for chart construction (trial events used LEGO® borrowed from St Peter's School, York) Undergraduate salaries (event coordinator and casual event delivery) Undergraduate internships (developing resources)	£10,000
STFC Small Award (2016): Virtual Binding Blocks programme - from plastic to digital bricks	Video production (externally produced) Minecraft virtual world development Undergraduate internships (developing resources)	£9,000
STFC Leadership Fellowship (2018): Engaging Education with Binding Blocks programme	20% Christian Diget's time over 3 years 10% Katherine Leech's time over 3 years 25% Graduate Intern time over 3 years 2x KICK-START PhD internships (3-months each) Travel and accommodation assistance for interns Additional materials to create School LEGO® Loan Kits and an additional Iron chart External evaluation	£124,000
Department of Physics, University of York, commitments to match Fellowship costs	Travel for ambassadors to attend training and events Undergraduate internships 2x KICK-START PhD internships (3-months each)	£21,000
IOP Exhibition Funding	Contribution to: Exhibition design and print costs Consumables for workshops Travel and accommodation costs for exhibition demonstrators	£2,500
Total		**£174,500**
Additional in-kind contributions:		
National STEM Learning Centre	Hosting / co-leading 12 teacher CPD courses	£54,000
Department of Physics, University of York	Additional 20% Outreach Coordinator time over 3 years 30% Administrator time over 3 years	£55,000

Appendix 2: Partnerships[102]

1 BIUST, Botswana
2 Daresbury Laboratory (STFC)
3 ELI-NP, Romania (European Researchers' Night)
4 Institute of Physics
5 iThemba LABS, South Africa
6 Lewis Matheson, GCSE and A level Physics Online
7 Lund University, Sweden
8 National STEM Learning Centre
9 Science, Technology and Facilities Council (STFC)
10 Sheffield Hallam University
11 The Australian National University
12 TRIUMF, Canada
13 University of Birmingham
14 University of Glasgow
15 University of Guelph (Canada)
16 University of Hull
17 University of Jyväskylä (European Researchers' Night)
18 University of Liverpool
19 University of Manchester
20 University of Surrey
21 University of the Witwatersrand, South Africa
22 University of Western Cape, South Africa
23 University of Zululand

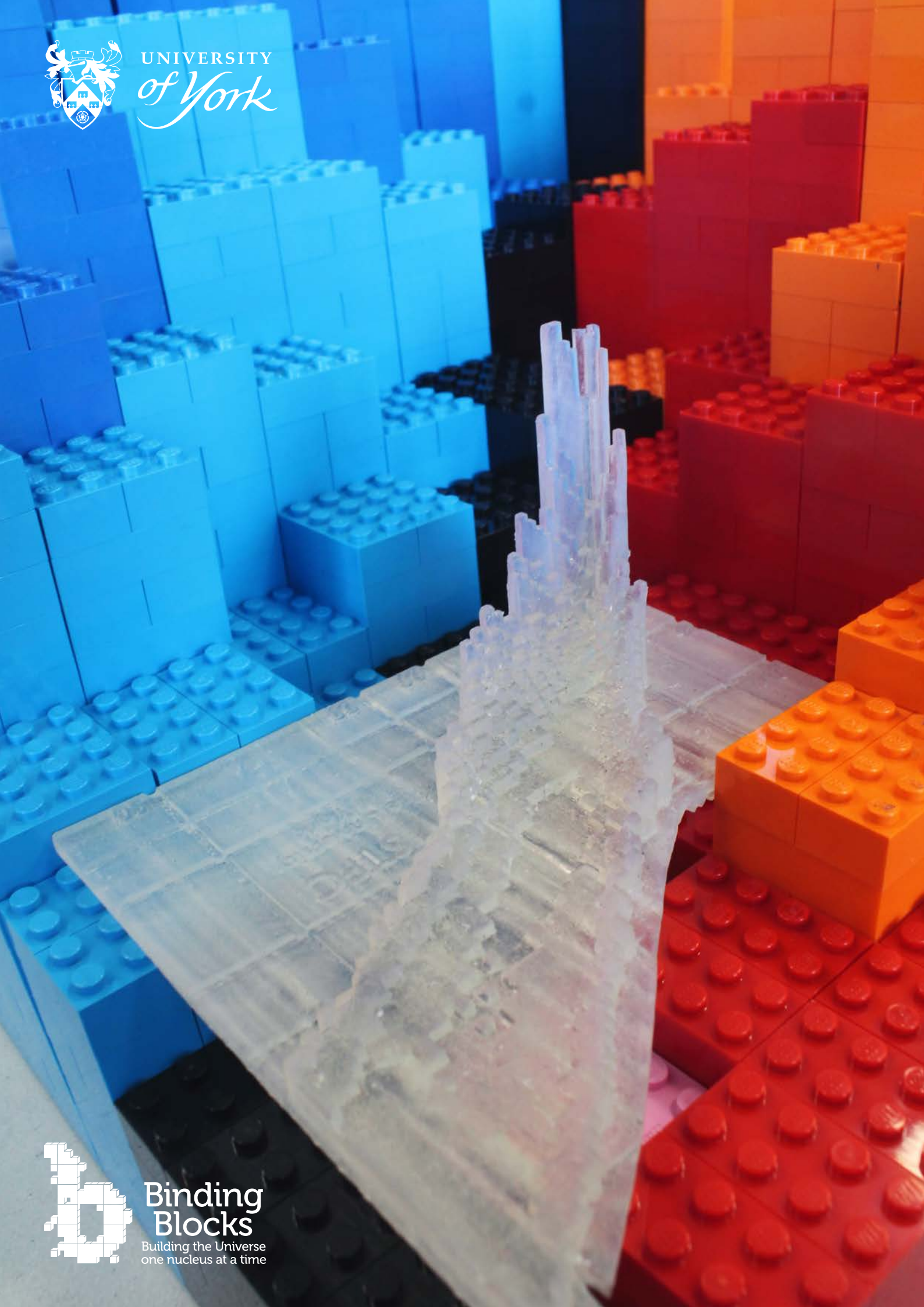
[102] Source: ResearchFish returns 2017-2020, reviewed and updated by the Binding Blocks team.

Appendix 3: Online Survey Sample

The student sample taking part in the Online Nuclear Physics masterclasses had the following characteristics:

- 55% were male. 45% of the sample were female. One person preferred not to say.[103]
- 24% (93 people) were from a BAME background (33% of the females taking part were BAME).
- 23% were part of the first generation of your immediate family to attend university (with females more likely to state this 27% compared to 20% of males)
- 9% (35) were eligible or had been eligible for Free School Meals at some point in the previous 5 years.
- 6% (20) has a disability or long-standing health condition
- 5% (15) received Bursary Fund payments from the Education Funding Agency
- 1% (4) were young carers
- Less than 1% (2) students had previously been in Local Authority care.

[103] N= 329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